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AN INTRODUCTION

TO THE

SCIENCE & PRACTICE OF PHOTOGRAPHY.



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TO THE
SCIENCE & PRACTICE
OF
PHOTOGRAPHY.

SECOND EDITION. REVISED AND ENLARGED.

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WITH NUMEROUS ILLUSTRATIONS.

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PREFACE.

THE demand for a new edition gives the Author an opportunity of expressing his thanks for the kind reception accorded to the first. He has endeavoured to correct the errors of the original volume, and to supply the deficiencies created in it by the progress of knowledge since its issue. To provide for the adoption of the metric system, which is undoubtedly growing in favour, formulæ are expressed in grammes and cubic centimetres per 1,000 cubic centimetres, as well as by the usual English method. Quoted formulæ are given as set down by their authors. The metric formulæ given are not the exact counterparts of the others, but the proportions are for all practical purposes the same. For the sake of those who are not accustomed to the metric system, it may be remarked that the unit bulk of 1,000 c.c. has been adopted for uniformity sake, as any bulk is easily calculated from it. If, for example, 50 c.c. of a developer are required, the figures given are halved, and the decimal point shifted one place to the left.

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THE
SCIENCE & PRACTICE OF PHOTOGRAPHY.

PART I.
PRELIMINARIES.

CHAPTER I.

INTRODUCTORY AND TO BEGINNERS.

PHOTOGRAPHS are spread abroad in such abundance, that it is not easy to imagine any person living in what we understand as a civilised country who has never seen a picture produced by light. There are, however, many individuals whose ideas of a photograph are summed up in what is technically called a silver print or a collodion positive; and those who have a definite notion of the manner in which these are produced are few and far between. A considerable number of even those who practise photography as a means of livelihood know very little of the changes they bring about.

A photographer must work intelligently if he is to work thoroughly and well; he must, in short, work scientifically. Although the artistic aspect of photography has very necessarily been prominently brought forward from time to time, it is never suggested that art study alone will make a photographer. Art principles indicate what is desirable in a picture, but it is the science of photography that tells us how preconceived ideas may be realised.

The object of this work is not especially to discuss the most recent modifications of positive printing, or the latest suggestions for developing; such matters as these are not altogether neglected, but we have chiefly to do with the fundamental principles out of which the practical formulæ of the past and the present have grown, and to which we must still look for further improvements.

The term photography is rightly applied to any process for reproducing writings, drawings, pictures, or designs of any sort in which light takes an essential part; and it is correct to call such a reproduction a photograph, although the proof has been done by a lithographer or in an ordinary printing press. It is not customary to apply the term "photographer" to everyone who takes part in the production of photographs, nor is this title earned by the purchase of a camera. The engraver is not only the owner, but the successful user of his tools, and must have had a varied experience of the processes of his vocation; and in calling him an engraver, we distinguish him from those who only assist him. It is convenient, as far as possible, to use the word photographer in a similar way.

Photographs cannot be taken in the dark, yet every photographer uses a dark room, and has special devices to keep out the light. Light is the power of the photographer, and he must have it perfectly under control. Light alone, however, gives results of little value. It cannot etch a plate, but it can produce changes in a resisting medium, and so guide the corroding liquid, and although it cannot make a negative, it gives us the possibility of developing one. In every case, perhaps, where a photograph is made, the action of light is supplemented by that of a chemical reagent.

Before entering, therefore, upon the consideration of what we may call the science of photography proper, it is advisable to become somewhat acquainted with the principles of chemistry and optics. The student may gain his knowledge of these matters from the ordinary text books that deal with them, but in that case a great deal of work will have to be done that is not of immediate use to him as a photographer. It has been the endeavour of the

author in the following early chapters to lay before the reader the principles of these sciences in a true and scientific way as far as they go, excluding all that is not of prime importance to the photographer.

But there are a few matters that are conveniently considered before entering upon these main branches of the subject. Anyone who wishes to study photography from a practical point of view should begin to work at once, even in his ignorance. His apparatus should be of small size, but good. There are cheap handbooks to be got that deal only with practical details and give simple directions, and such a book, or the kindly help of a friend, or a few *bonâ fide* lessons from someone who is able to teach (this is the most expensive but the easiest), will help the beginner into the way of using his apparatus. Or he may, if he prefer it, turn to those chapters in this volume that deal with the production of negatives and silver prints on albumenised paper.

The first thing to be photographed should be a black and white flat subject, such as an impression from a large woodcut. The coarser or thicker the black lines or patches the better will it answer the purpose. He should expose plate after plate in the camera, after focussing such an object as sharp as he possibly can, until he finds he can develop a negative with its transparent parts quite or nearly free from any deposit, and its dark parts very decidedly dark when held up close in front of a good gas or lamp flame. Many faults will show themselves in this simple exercise that will not need an expert to detect, and these must be resolutely fought against until a certain degree of manipulative power is gained. After this a good bright-looking cabinet size photographic portrait may be set up to experiment upon, to get practice in the reproduction of different depths of shade. Then a simple object out of doors, from twelve to twenty feet away from the camera, may advantageously be photographed before going further afield.

About twenty-five years ago, a photographic journal, in referring to an invention that has long since been superseded, said that "the process of taking views was reduced

to a mere mechanical operation, and the complicated art of photography brought down to the meanest capacity. An hour's instruction from an adept would be sufficient to convert the timid amateur into the accomplished artist." It would be a sorry time for photography if this state of things were ever to come to pass, and it is quite certain that at present nothing but patient and persevering practice will give the skill of an ordinary operator, the "accomplished artist" resulting only where natural talent is present with this practice.

CHAPTER II.

THE APPLICATIONS OF PHOTOGRAPHY AND THE HISTORY OF ITS DEVELOPMENT.

THE ends that photography has been made to serve are so numerous that we can do little more than catalogue the chief of them.

The "artist" often photographs instead of sketching, because in this way he gets more rapidly and exactly what he wants; and the reproduction of celebrated paintings and the like by photographic means now forms an important branch of industry.

The sculptor and the architect find that photographs are not only cheaper, but more reliable than other representations. It would be difficult to find an estate agent who never showed a photograph in furtherance of his client's interests. The wood engraver is not dependent upon the draughtsman, for the block is drawn upon by the agency of light; and the engraver himself often finds his work done both cheaper and better by some one of the many photo-mechanical processes.

The military engineer photographs foreign fortifications, and finds the camera more rapid and reliable than the draughtsman in recording the results of artillery experiments. There is a permanent staff of photographers at Shoeburyness who make permanent and unbiased records of the results of all the experimental work carried on there. The pigeon post, which was so useful during the siege of Paris, was made possible by photographic means, and it is stated that as this method of conveying despatches has proved itself indispensable in certain emergencies, the Germans have established a regular service of pigeons in the chief fortresses of the empire.

Civil engineers generally have photographic establishments in connection with their workshops. The previously

laborious task of reducing maps from one scale to another is now done more quickly and exactly, and at less expense, by photographic means.

The scientific investigator also prefers photographic records as being unbiased and permanent. A ray of light is caused to draw its own curve to represent the movements of thermometers, barometers, magnets, &c. The astronomer, indeed, is finding that photography can detect what is not visible to the eye, because the photographic effect is cumulative.

By means of photographs foreign lands are made familiar to us, and those of our photographs that are permanent will certainly become valuable as records of manners and customs when a few generations have passed away. Priceless unique documents might be copied by the camera, and as the reproductions would serve the purposes of classical research, the originals would suffer less injury, and if they were destroyed they would not be lost to us.

Some problems in natural history, such as the methods of the movements of animals, can be solved only by photographic means. And if we had a mind to do so, we might continue to multiply instances of the applications of photographic processes, for we have not mentioned their uses to the police detective, in ordinary portraiture, in picture-making, and in other matters that are more or less familiar.

Although the practical applications of photography have followed one another very closely, and the art itself is little more than fifty years old, the beginnings of things that have made photography possible date back to about three hundred years ago.

In A.D. 1556, the alchemists observed that chloride of silver darkened when exposed to the light.

In 1589, or a little earlier, J. B. Porta invented the camera.

In 1727, J. H. Schulze got copies of writing in sunshine by means of nitrate of silver solution mixed with chalk.

In 1737, Hellot used nitrate of silver and chloride of gold solutions on paper.

In 1757, J. B. Beccarius used chloride of silver.

In 1770, Scheele showed that violet was the most active light in darkening chloride of silver.

In 1774, Scheele isolated chlorine.

In 1777, he found that chloride of silver lost chlorine when it was exposed to the light in water.

In 1796, Brougham suggested the possibility of getting a picture on ivory moistened with nitrate of silver, and exposed in a camera.

In 1801, Ritter found that chloride of silver was darkened by the ultra-violet of the spectrum.

In 1802, a paper by Thomas Wedgwood (son of the great Wedgwood) and Humphrey Davy was read at the Royal Institution on copying paintings done on glass, and making profiles by means of nitrate of silver. Davy found that chloride of silver was better than the nitrate, and that leather was better than paper. Some photographic prints were got by means of the solar microscope, but these experimenters failed to find a fixing reagent.

In 1810, Seebeck observed that when the solar spectrum was projected upon moist chloride of silver on paper, some approximation to the natural colours was produced.

In 1812, Courtois discovered iodine.

In 1813 or 1814, Joseph Nicéphore de Niépce coated metal plates with a film of bitumen, exposed them in the camera for some hours, and dissolved away the still soluble unaffected parts of the film with oil of lavender. It appears that by 1826 he had so far perfected this process of heliography as to have etched his developed plates, and to have got prints from them after the manner of copper-plate printing.

In 1819, John Herschel described the hyposulphites and the solvent power of the alkaline hyposulphites upon chloride of silver.

In 1824, Daguerre began experiments on much the same lines as Niépce, hoping to make permanent the pictures produced by the camera.

In 1826, Balard discovered bromine.

In 1827, Niépce was refused a hearing at the Royal Society, although he showed his specimens, because he declined to explain the details of his process.

In 1829, Niépce and Daguerre entered into partnership.

In 1833, Niépce died. Daguerre continued the work, and from using iodine to stain the surface of his silver plates was led ultimately to the invention of the Daguerreotype process.

Fox Talbot is stated to have begun his researches in this year, and in 1839 he stated that several pictures of a country house which he then showed had been taken in the camera in 1835.

In 1838, Daguerre explained his process, the Daguerreotype, to Humboldt, Biot and Arago. Through Arago's influence, Daguerre had a pension of 6,000 francs per annum on condition that he surrendered his rights in his process.

On August 14th, 1839, the Daguerreotype process was patented in England, and five days afterwards it was publicly explained in Paris, and given free to the world (except England).

In this year also, Fox Talbot described his process of "photogenic drawing," in which he used paper impregnated with common salt, and sensitised with nitrate of silver, and fixed the image with a saturated solution of common salt. He produced both negatives and positives. He also substituted bromide of potassium for common salt to get the sensitive surface. John Herschel recommended hyposulphites for fixing. He exhibited, at the Royal Society, photographs made by himself, one of which was a picture of his telescope, and taken in a camera. J. B. Reade used an infusion of nut-galls (whence we get gallic and pyrogallic acids) to render nitrate of silver on paper more sensitive to light, and he fixed with hyposulphite of soda. And Mungo Ponton pointed out that paper soaked in a solution of bichromate of potash and dried was changed by exposure to light, and that the chromium compound produced by light could not be washed away.

In 1840, John Herschel used the terms "positive" and "negative," as they are now understood photographically, "to avoid circumlocution." He used glass plates to receive and support the deposit of sensitive silver compound. Bromine was introduced for photographic purposes, as

applied to the preparation of the Daguerreotype plate, by Goddard, and in other ways by Bayard.

In 1841, Petzval invented the lens that bears his name, and Voigtländer constructed it. Fox Talbot patented his calotype process, in which iodide of silver was used on paper, and great sensitiveness was got by means of a solution of gallic acid with nitrate of silver, and the scarcely-visible image produced by exposure was developed with more of the same solution. One minute's exposure with an aperture of $\frac{f}{17}$ was sufficient for a building in sunshine. Claudet patented the use of coloured media, preferably red, through which the "dark room," which was till then really dark, was illuminated.

In 1842, John Herschel described methods of printing with iron salts, including the production of prints in Prussian blue.

In 1844, Robert Hunt introduced ferrous sulphate as a developing agent.

In 1848, Niépce de St. Victor introduced the albumen process, in which glass is coated with albumen that contains iodide of potassium, and the film is sensitised by dipping it into a solution of nitrate of silver (the silver bath).

In 1851, F. Scott Archer introduced collodion, which was first suggested for photographic purposes by Le Grey.

In 1852, Fox Talbot described photo-etched plates, prepared by coating the plate (or lithographers' stone) with a mixture of gelatine and bichromate of potash, exposing under a negative, washing and etching.

In 1854, "The Art Journal" gave an impression from a woodcut, engraved from a photographic impression on the wood.

In 1858, "The Photographic News" also gave a specimen.

In 1864, B. J. Sayce and W. B. Bolton used collodion emulsions.

And in 1871, R. L. Maddox used gelatine instead of collodion.

On looking over this meagre sketch of the history of our subject, we see that the art of photography is little

more than fifty years old, and that 1839 was the most important year of its development. The publishing of Daugerre's process at that time was a powerful incentive to other workers, especially Fox Talbot, to complete and to bring forward the results of their investigations; and we may safely say that if Daguerre had never employed himself with this subject the world would not have had to wait much longer for the advantages of photography. The fruit of the labour of many previous workers was fast ripening, and it was almost by accident that Daguerre happened to find it fully ripe before any of his contemporary workers; but to him must ever belong the glory of having first made photography usefully possible.

CHAPTER III.

THE CHEMICAL ACTION OF LIGHT AND PRELIMINARY CHEMICAL MATTERS.

PHOTOGRAPHY is little more than a practical application of the chemical action of light. We do not know what light is, but we do know in many cases the effects that it produces. We know also that sunlight is not homogeneous, but that it may be separated into lights of different colours, as in the rainbow. Therefore, in speaking of "light" without further qualification, the word is used in its commonly accepted sense, and generally refers to the light that reaches us from the sun.

The chemical action of light is universally known, though perhaps not often recognised as such. The housewife keeps her blinds drawn down to prevent the fading of the curtains and carpets; and the bleaching action of light was usefully applied before chlorine compounds in the preparation of cotton fabrics. Shortly before the Christian era, Pliny observed that yellow wax lost its colour by exposure to light. The destruction of colour, however, is not characteristic of the chemical action of light, for we have already noticed how that chloride of silver is darkened by exposure, and the green colouring matter of plants, the chlorophyl, is not produced in the roots which are below ground, nor in the plant at all if it is grown in the dark. Light causes the separation of chlorine from its compound with silver, but it causes chlorine to combine explosively with hydrogen if the two gases are mixed and placed in the sunshine. Hence, we must not imagine that light is especially either a destroyer

or a builder up of compounds, any more than heat or any other force is ; its action depends upon the circumstances of the case.

Whether chemical action is produced by light, as in photographic printing, or by other substances (they are called "reagents" in chemical language), as in developing, or whether it takes place spontaneously (the cause not being very obvious), the change or reaction proceeds according to the same general rules.

All substances that we deal with must be either compounds or elements. Every compound can be either decomposed—that is, pulled to pieces—or can be built up from its constituents ; but the elements cannot be decomposed. For example, if we were to make the dry crystals of chloride of gold red hot, this compound would be decomposed, that is, the gold and the chlorine would separate from one another ; but we may do whatever we please to a piece of iodine, or of silver, we cannot by any known means get anything whatever but iodine from the iodine, or silver from the silver. They may be ground up, melted, volatilised, but the iodine always remains iodine, and the silver is always silver.

An element cannot suffer chemical change ; whenever it enters into a chemical action, it can only combine with something else. When a silver plate is sensitised for the production of a Daguerreotype, it is exposed to the vapour of iodine, and the sensitive film is produced by the combination of the silver and the iodine. In this case two elements combine to form a compound. There are circumstances, however, that sometimes make it not advisable to use the simple element when we want to get a compound containing it. If an over-dense negative is to be reduced, we may desire to change a part of the silver image into chloride of silver, that hyposulphite of soda may dissolve it away ; and this change could be produced by applying the element chlorine. But chlorine acts very vigorously in combining with other things, and would probably spoil the negative. The silver, moreover, can very readily take chlorine from the compound of chlorine with iron, called

ferric chloride or perchloride of iron, leaving the iron with less chlorine; and as this compound is very much less likely to injure the negative, it is a preferable reagent to the simple chlorine. An element will often form a compound by taking what it combines with out of another compound.

Compounds invariably have very different properties from the elements they are composed of. Sulphate of iron, for instance, contains the tough metal iron, the yellow sulphur, and gaseous oxygen, but the compound is not tough, nor yellow, nor gaseous. Pyrogallic acid is a compound of carbon, oxygen, and hydrogen; and although each of these elements can be easily got out of it, so long as they remain joined together their individual characters are entirely lost—the compound bears no resemblance whatever to either of its constituents.

There are nearly seventy elements known, but only about twenty of these are of sufficient importance to the photographer to make it worth while to introduce them into this short sketch of photographic chemistry. It is the custom of chemists to indicate the elements by their initial letters, or by the initial letters of their Latin names, sometimes adding a second letter to avoid confusion. And these “symbols” do not stand merely for the elements, but for a definite proportion by weight of each; for example, the two symbols which together constitute the “formula” of hydrochloric acid, HCl , indicate not only that the compound consists of hydrogen and chlorine, but also that it consists of these elements in the proportion of one part by weight of hydrogen to 35.5 parts by weight of chlorine.

The proportional weights assigned to the elements are termed the “atomic weights,” that is, the proportional weights of the atoms, and the symbols are taken as standing for the atoms. This part of chemical theory has a far deeper significance than it is necessary or desirable to enquire into here.

The following table gives the names of the elements.

that are most important photographically, with their symbols and atomic weights :—

NON-METALS.				METALS.			
NAME.	SYMBOL.		ATOMIC WEIGHT.	NAME.	SYMBOL		ATOMIC WEIGHT.
Hydrogen ..	H	..	1	Potassium ..	..	K	.. 39
Chlorine ..	Cl	..	35.5	Sodium ..	..	Na	.. 23
Bromine ..	Br	..	80	Ammonium*	..	Am	.. 18
Iodine ..	I	..	127	Silver ..	..	Ag	.. 108
Oxygen ..	O	..	16	Calcium ..	..	Ca	.. 40
Sulphur ..	S	..	32	Lead ..	..	Pb	.. 207
Nitrogen ..	N	..	14	Copper ..	..	Cu	.. 63.5
Carbon ..	C	..	12	Iron ..	..	Fe	.. 56
				Mercury ..	..	Hg	.. 200
				Gold ..	..	Au	.. 197
				Platinum ..	..	Pt	.. 195

All compounds have a definite composition, which can be expressed in most cases by a very simple formula. Thus table salt or chloride of sodium is expressed as NaCl , and this formula, in conjunction with the above table, shows at once that this substance contains 23 parts by weight of sodium and 35.5 parts by weight of chlorine. Corrosive sublimate, which is written HgCl_2 , contains 200 parts by weight of mercury, combined with twice 35.5 (that is 71) parts by weight of chlorine. The proportion between the constituents of any given compound does not vary, but commercial preparations vary by being mixed with more or less of foreign matter which may have been not entirely removed in the manufacture, or which may have been produced by the decomposition or change of a part of the preparation.

Mixtures, however, are totally different from compounds. Sugar and salt may be ground up together in any proportions whatever. Two or more gases, such as nitrogen and oxygen, can be mixed in any proportions, and the same often applies to liquids, such as water and alcohol.

Such mixtures as those just instanced are readily prepared, but when it is desired to mix a solid with a liquid, there are difficulties that have to be overcome. Sand will

*As ammonium consists of two elements, nitrogen and hydrogen (NH_4), it is neither an element nor a metal, but it is convenient to include it because it behaves like a metal.

hardly mix with water, it soon settles down, but fine mud will remain in suspension for a considerable time. It is possible to get gold in such a fine state of division that it will remain for years before it settles down from the water it hangs in.

An "emulsion" is a milk-like liquid, having particles of such a degree of fineness suspended in it, that the ordinary methods of separating solids from liquids are almost ineffectual. Ordinary filtering media allow emulsions to pass through them, and the solid matter subsides very slowly.

However fine the particles of an emulsion are, they can be separated from the medium that holds them, and they are still solid, but when a solid substance is "dissolved" in a liquid, the most refined methods of filtration entirely fail to effect a separation. A dissolved compound is not chemically combined with its solvent, for the proportions of the two may be varied within certain limits, but the union is something closer than that of a mere mixture. The dissolved substance may generally be recovered by evaporating away the solvent, or by changing the solvent in such a way as to rob it of its dissolving power. Colloidion, for instance, is a solution of what is called soluble gun-cotton in a mixture of alcohol and ether, and the gun-cotton may be recovered in the solid condition either by evaporating off the alcohol and ether, or by adding water, because alcohol and ether mixed with sufficient water cannot dissolve the gun-cotton.

It is often desired to obtain one constituent of dissolved matter in a solid form, the nature of the solid being quite a secondary matter so long as it contains the particular constituent; for example, the silver in waste solutions. In such cases it is convenient to "precipitate" what is wanted by adding something that will make an insoluble compound with it, as for silver, the sulphide of sodium, which produces the black insoluble sulphide of silver.

CHAPTER IV.

THE AIR AND OXYGEN AND ITS COMPOUNDS, ETC.

THE air forms a very important item in photographic operations. Although it is invisible, it is often inconveniently obtrusive to the out-door worker, being sometimes a positive barrier to his progress; it is essential to the operator in the dark room, but detrimental to the processes he has to carry on. But there is one point that should ever be borne in mind—namely, whenever air is harmful, foul air is more so. All places must be ventilated, but dark rooms, which are generally small, especially require plenty of fresh air, and with a minimum of dust and damp. An unventilated or badly-ventilated dark room will deteriorate the work done in it by the direct action of the bad air, and also because semi-suffocation dulls the wits of the operator.

Combustion and respiration both work in a similar way to vitiate the air, using up its oxygen, and producing carbonic acid and water. Although these products are heavier than air when they are cold, being hot when liberated they are lighter than the air, and ascend. The accumulation of foul air at the tops of rooms is the key to efficient ventilation; it is from here that it must be drawn off, and fresh air should be introduced at a lower level, so as not to disturb the top layers of unwelcome gases. The higher a room is, the more space is provided for the foul air, and ventilation becomes less urgent. If sensitive material—plates, paper, etc.—must be kept in places where gas is burned and where people breathe, they should never be stored higher than about six feet from the floor, so that anyone walking in the apartment inhales the worst air likely to gain access to the sensitive material. Neglect of these simple precautions has given considerable trouble to manufacturers, dealers, and photographers.

It is very easy to show that the oxygen of the air—that is, the useful part of it—forms only about one-fifth of its total bulk. The other four-fifths is nitrogen, which simply dilutes the oxygen. If a wet medicine phial has a few iron filings introduced into it, is shaken so as to spread them over its inner surface, and is then placed in an inverted position with its mouth under water, it will be found that the water will gradually rise in the bottle, until in a day or so it will be about one-fifth full of water. The water that rises into the bottle occupies the space that was filled by the oxygen, and the oxygen has combined with the iron.

Developers absorb the oxygen of the air, especially when they are spread out into a thin layer as they are in developing, and the compounds produced are worse than useless, because they are dark coloured and are liable to stain the gelatine. Whatever developer is used, a sufficient quantity must be taken to allow for loss and deterioration by exposure to the air during development.

The air always contains carbonic acid, normally about .04 per cent., but this amount is much increased in ill-ventilated rooms. This gas is subsequently referred to.

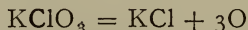
The water or moisture that is present in the air often causes the photographer much trouble in other ways than by the leakage of rain through skylights, or their breakage by hail or snow. The amount of the invisible vapour of water in the air is being constantly augmented by the evaporation or drying up of water, whether from wet pavements, clothes hung out to dry, or the surfaces of ponds, rivers, or oceans. We can easily condense enough of the water from the air to get a visible quantity by means of a cooled surface, such as a tumbler containing spring water or ice. The air that is in immediate contact with the outer surface of such a glass is lowered in temperature and made unable to retain its moisture, which is therefore deposited upon the cooled surface. If a cold lens is brought into a warm room, it will generally be rendered useless for a time by the moisture that is deposited upon it. In such a case the instrument should be left in a warm part of the room for a few minutes until the moisture

has disappeared. Wiping will not effect a cure, for unless the lens has happened to get warmed during the operation, a fresh deposit of moisture will soon be formed.

There are some substances that take up water with such eagerness that they will dry the air they are in contact with, sometimes becoming liquid themselves. Carbonate of potassium and chloride of calcium are such compounds. Strong sulphuric absorbs water vapour with greater avidity than either of these salts, but it is obviously not always convenient to use. The paper prepared for platinum printing will give good results only when kept carefully dry, and this is accomplished by storing it in boxes that have chloride of calcium below perforated false bottoms. The chloride of calcium is mixed with asbestos and tied up in muslin to prevent the fine particles from getting on to the paper.

As we have already seen, the air consists chiefly of oxygen diluted with four times its bulk of nitrogen. Oxygen is more abundant than any other element. Besides being present in the air, it constitutes eight-ninths by weight of water, and is doubtless the element present in the greatest quantity in the solid part of the earth's crust. Flints contain more than half their weight of oxygen. This gas is needed in an almost pure condition for the production of the oxy-hydrogen light, and for other purposes in artificial illumination.

Although the statement reads like a truism, it is worthy of note that oxygen can only be obtained from something that contains it. Chlorate of potassium is the most convenient substance to use, and by mere heat it breaks up into potassium chloride and oxygen. The chemical equation is written thus—



and signifies that one molecule of the salt yields three atoms of the gas. The weight of the molecule of the chlorate found by adding together the weights of its constituent atoms is 122.5, and the weight of the three atoms of oxygen is 3 times 16 = 48. These figures, 122.5 and 48, show the proportion that always exists between the weight of the chlorate of potassium and the weight of the oxygen

gas producible from it. The method of discovering the volume of any given weight of any gas is described in connection with hydrogen.

In preparing oxygen for practical purposes, it is necessary to mix the chlorate of potash with about half its weight, more or less, of the black oxide of manganese. The amount of oxygen is not changed by this addition, but its evolution is rendered much more rapid even at a lower temperature. The part that the manganese takes in the reaction is not understood.

It should be noted that neither the chlorate of potassium nor the manganese must be dirty from the presence of ordinary dust or anything that will burn. It is safer to heat a little of the prepared mixture first in an iron spoon or glass test tube, and if any appreciable sparkling takes place, the mixture must be rejected as dangerous.

Oxygen is very little heavier than the air. Combustible things burn in it much as they do in the air, but more rapidly, producing a higher temperature because of the absence of nitrogen, and therefore more luminosity. A match with only a spark upon it bursts into flame when plunged into the gas. The artificial light for portraiture invented by J. Y. McLellan consists essentially of a globe that can be filled with oxygen as required, in which magnesium wire is burned.

When substances are burned they are not lost, but new bodies are produced by their combination with oxygen. When the material burned is an element, the product is simply an oxide; and if a compound such as tallow, wax, or coal is burned, we may consider that each element is acted upon as if it were alone. Coal, for example, gives carbonic anhydride (or carbonic acid, CO_2) from its carbon, water (H_2O) from its hydrogen, and sulphurous anhydride (or sulphurous acid, SO_2) from the sulphur that may be present.

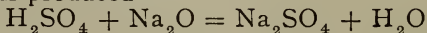
The non-metals, except hydrogen, generally produce, by their burning, substances that are soluble in water and form acids when they are dissolved. Such a compound of oxygen is called an "anhydride." Metals, when they burn, produce what are called "oxides" or "bases,"

and these, if soluble in water, have properties that are the reverse of the acids. They change red litmus paper to blue, while the acids change blue to red; and they are slimy or soapy to the taste, instead of sharp and penetrating. These properties are termed "alkaline," and are exemplified in ordinary washing soda.

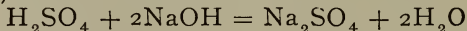
If an anhydride and a base are brought together they generally combine, and the distinctive properties of both are lost in the resulting compound, which is called a "salt." Sulphuric anhydride, SO_3 (which can be produced from sulphurous anhydride, SO_2 , by adding more oxygen), will combine with the oxide of sodium to form the salt called sodium sulphate (or sulphate of sodium, or sulphate of soda). The salt has none of the distinctive properties usually associated with acids or alkalies, and its characteristic taste is referred to as "saline." The change that takes place during its production in this way is expressed chemically thus—



If we use the acid—that is, the anhydride plus water—instead of the anhydride, the water involved is eliminated as the salt is produced—



And if, instead of the oxide of the metal, we use the compound produced by adding it to water—that is, its "hydrate," we have this water also eliminated.



There are some acids, such as hydrochloric acid, HCl , that have no oxygen in their composition, and that therefore cannot be built up of an anhydride and water. But all acids agree in containing hydrogen, and if we speak of a salt as an acid with its hydrogen replaced by a metal we have a description that is universally applicable.

Every salt can be made to furnish an acid and a base. All salts are not neutral to test paper. Carbonic acid, for instance, is so weak an acid that it cannot neutralise the alkalinity of the soda when it joins with it to form sodium carbonate. This compound, however, is none the less a salt, for it has its acid and its base.

An acid and a base can very rarely exist side by side;

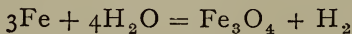
they will combine to form the corresponding salt. If we add citric acid to restrain an alkaline developer, we have not simply added a restrainer, as when bromide of potassium is added, but the acid combines with some of the alkali to form a salt—that is, a citrate—and we have lessened the amount of free alkali as well as introduced the restrainer. But two or more acids, or two or more alkalies, can exist side by side, each as if the other was not present. The notion that birds of a feather flock together has no application in chemical changes.

Referring back to the matter of combustion, we see that a rise of temperature is conducive to chemical action, and that the converse is also true—chemical action generally leads to a rise in temperature. Whatever warming effect we desire is produced by chemical action, as in the combustion of ordinary fuel. But we are apt to forget that the chemical changes we need to bestow the maximum of care over are accelerated by a rise of temperature. The toning of silver prints may scarcely proceed in the winter time until the solutions are warmed, and developers that are well suited for the average English climate must be weakened or more restrained in the hot weather or in a tropical country. An even temperature in the operating room all the year round is not only a comfort to the operator, but an element of uniformity in his work.

CHAPTER V.

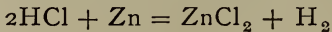
CONCERNING HYDROGEN, THE COMBINING POWER OF THE ELEMENTS, AND CERTAIN PROPERTIES OF GASES IN GENERAL.

WATER contains eight-ninths of its weight of oxygen, the other ninth is hydrogen. Hydrogen is a gas, and it is the lightest substance known. It is only one-eighth the weight, bulk for bulk, of the next highest substance, so that its lightness is exceptional and characteristic. The chemical formula of water is H_2O , and the hydrogen can be set free from this compound by passing steam through a red hot tube containing iron filings or nails. The change that takes place is represented thus—



The oxide of iron produced is black, and forms a closely adherent film upon the surface of the metal. When carefully produced this coating is usefully protective to the metal beneath, and ornamental ironwork and culinary apparatus are sometimes treated with steam at a high temperature, the oxide produced serving instead of enamel or paint. This black oxide is the most stable of all the oxides of iron; it will not readily react with acids to form salts.

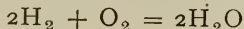
But it is far more convenient to get hydrogen from hydrochloric acid by the action of zinc. The metal will decompose the acid alone in the gaseous condition, thus—



forming chloride of zinc and hydrogen; but it is better to use the aqueous solution of hydrochloric acid (that is, the "hydrochloric acid" of commerce), and to add this, a little at a time, to the zinc after covering it with water.

The water dissolves the chloride of zinc produced, and so keeps a clean surface of metal for the acid to act upon.

Hydrogen will burn readily in the air, combining with the oxygen in the air to form water (H_2O).



This equation indicates the proportion that exists between the volumes of hydrogen and the oxygen with which it combines when it burns, if we bear in mind that an equal number of molecules of any gas occupy the same space under uniform conditions of temperature and pressure; or, in other words, that the bulks of gases are proportional to the number of molecules. As in the above equation two molecules of hydrogen require one molecule of oxygen, we may say that two volumes (pints, litres, &c.) of hydrogen will combine with one volume (pint, litre, &c.) of oxygen when it burns. This combination is gradual and safe when the hydrogen burns from a jet, but if the gas is mixed with the oxygen or air that it requires for combustion, and a fire is put to the mixture, the whole bulk of gases burns almost simultaneously, the high temperature produced by the burning is developed suddenly instead of gradually, and we have an explosion with its unwelcome concomitants.

Of all the gases that the photographer is likely to have to deal with, perhaps hydrogen is the most likely to lead to accidents, and as coal gas is, roughly speaking, about half hydrogen, we do not go very far wrong in saying that whatever precautions are necessary in dealing with hydrogen are also necessary with coal gas.

Hydrogen is not only exceptionally light, but in the movements of its particles it is far more agile than any other substance. If we were to try to fill a vessel made of unglazed earthenware or plaster of Paris with hydrogen by passing the gas into it, we should find our attempts unsuccessful, because the gas would rapidly escape through the minute pores of the material. Under these circumstances, as the hydrogen passed out the air would pass in, so that a mixture of gases would be obtained in the vessel, and perhaps an explosive mixture. Minute holes or pores in gas bags lead to similar results when the bags are not under

pressure, and are very likely to cause accidents. A gas-holder or gas-bag that is not certainly in perfect condition may be safely used for oxygen, because this gas is slower in its movements than hydrogen, and will be useful, or at least never dangerous, when mixed with even a large proportion of air.

This property that gases have of passing through porous substances is called "diffusion." The diffusion of gases takes place at a rapidity that is inversely proportional to the square roots of their densities or specific gravities; for example, in the case of hydrogen and oxygen the densities are as 1 to 16, the square roots of these figures are 1 and 4, and reversing these we get 4 and 1 as the relative rates of diffusion of hydrogen and oxygen.

As hydrogen is the lightest gas, it is convenient to take it as the unit of weight instead of air. The proportional weights or specific gravities of the simple gases are then expressed by the same figures that indicate their atomic weights; that is, oxygen is sixteen times heavier than hydrogen, nitrogen fourteen times, and so on. And if the weight of a unit volume of hydrogen is known, the weight of the same volume of any other gas is easily calculated. As a matter of fact, one litre of hydrogen weighs $\cdot 0896$ gram. To take an example of the usefulness of these figures, we may suppose it to be required to find what bulk of oxygen can be got from a given weight of potassium chlorate. We have already seen that the weight of potassium chlorate is to the weight of oxygen as 122.5 is to 48. If the calculation is made in grams, the bulk of gas is readily got by dividing the weight of oxygen by $\cdot 0896$ multiplied by 16, the result being in litres. Or, if it is desired to work with English weights and measures, the following table will prove useful:—

1 oz of hydrogen	} measure	{ 558.4 pints,
or 16 oz. of oxygen		
		or 11.3 cubic feet.

As an illustration of the way to use these figures, we will suppose that a gas-holder or bag that has a capacity of three cubic feet is to be filled with oxygen, and it is desired to know how much potassium chlorate should be

taken for the purpose. As 11·3 cubic feet of oxygen weigh 16 oz., three cubic feet of the gas weigh 4·24 oz., which is the weight of oxygen required. It has been shown above that the proportion between the weight of oxygen and that of the potassium chlorate required is as 48 to 122·5. Then, if 48 oz. of oxygen are furnished by 122·5 oz. of potassium chlorate, 4·24 oz. of oxygen will be yielded by 10·8 oz. of potassium chlorate. A calculation so made gives the weight required of the absolutely pure and dry salt, if the operation is carried out perfectly and with no loss; therefore, to allow for contingencies, from 11 to 12 oz. should be taken instead of 10·8 oz.

Hydrogen is also the unit in comparing combining power. Some elements have, atom for atom, a combining power equal to that of hydrogen; some have a greater, but none have less. Combining power is called "valency," or, less wisely, "atomicity." The valency of the few elements that we have included is shown in the following table:—

ONE.	TWO.	THREE.	FOUR.	FIVE.	SIX.
H	O	N	C	N	S
Cl	S	Au	S		
Br	Ca	Fe			
I	Fe				
K	Hg				
Na					
Am					
Ag					
Hg					

The use of this table is very simple. If the formula of chloride of gold is wanted, we find that gold has three times the valency of chlorine, and that therefore one atom of gold will be equal in combining power to three atoms of chlorine, AuCl_3 ; but chloride of sodium is NaCl , because both elements have an equal valency. The oxide of gold would be one and a-half of oxygen to one atom of gold, and as half atoms are not allowed, the formula becomes Au_2O_3 . The formula of sulphuric acid being H_2SO_4 the expression for any sulphate can be got by replacing the hydrogen of the acid by an amount of the metal that is of equal combining power; K_2SO_4 , or CaSO_4 , because one

calcium or two potassium atoms are equivalent to two hydrogen atoms.

Some of the elements occur two or three times in the above table, because they form two or three series of compounds. In such cases those compounds in which the metal has the lower valency are designated by the adjective termination "ous" to the metal, and those with the higher combining power have the termination "ic." Thus ferrous chloride, FeCl_2 ; ferric chloride, FeCl_3 ; mercurous chloride, HgCl , mercuric chloride, HgCl_2 . It is customary with some always to write two atoms of mercury in mercurous salts, and two atoms of iron in ferric salts, thus Hg_2Cl_2 , and Fe_2Cl_6 ; but this does not interfere in any way with the proportions. The simpler method is sufficient, and equally useful.

Sulphur occurs in three columns in the table, showing its condition in sulphides, sulphites, and sulphates respectively.

CHAPTER VI.

WATER, PEROXIDE OF HYDROGEN, AND OZONE.

WATER is the most important of all the compounds that contain hydrogen, and is produced whenever this gas is burned—whether it is alone or combined with other substances as in ordinary fuel. Water can easily be separated into its constituent elements, and the proportions in which these are present have been proved beyond a doubt. Pure water, however obtained, has invariable properties under uniform conditions; it is neither acid nor alkaline; it is colourless except in layers of considerable thickness, when it transmits blue light; it is tasteless; it boils at 100°C . (212°F .), and solidifies to ice at 0°C . (32°F .) It vaporises at all temperatures; even ice and snow give off vapour when the air is below the freezing point, but, other things being equal, it vaporises more rapidly at a higher temperature.

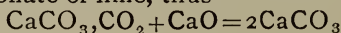
Gelatine plates, carbon tissue, prints, &c., &c., are dried by the evaporation of the water from them. A high temperature favours drying, but a high temperature without ventilation is useless, for at any temperature below that of boiling water, air may be “saturated” with moisture. This moist air must be removed to allow drier air to come and carry off its load of moisture. The hotter the air is, the more water it can hold before becoming saturated.

Water combines with many substances, often liberating much heat as it does so. The slacking of lime is a familiar example; here the lime (CaO) combines with water to form the hydrate of calcium (CaH_2O_2). Blue vitriol, or sulphate of copper, is found as blue crystals which contain water ($\text{CuSO}_4, 5\text{H}_2\text{O}$). The sulphate of copper without the water is neither blue nor crystalline. This water is called “water of crystallisation.”

Water is the most universal and useful solvent, and is never pure, because it dissolves a certain proportion of

whatever it comes into contact with. Our natural sources of water are supplied from the clouds, and even rain-water is not pure; it contains dissolved oxygen, nitrogen, carbonic acid, and other gases in less proportion, that it has taken up from the air. As ordinarily collected, it has also whatever it can gather as it passes over roofs and gutters on the way to its tank. River water contains, in addition, a modicum of earthly matter of a nature determined by the soil over or through which it has flowed. If the soil is purely sandy, the amount of matter imparted to the water is infinitesimal, but gypsum (that is, sulphate of calcium or sulphate of lime, CaSO_4) is soluble in five hundred times its weight of water. Chalk or limestone (that is, carbonate of calcium or carbonate of lime, CaCO_3) is not appreciably dissolved by pure water, but if carbonic anhydride (CO_2) is also present it forms with the calcium carbonate the soluble bicarbonate of lime ($\text{CaCO}_3.\text{CO}_2$). The carbonic anhydride is rarely lacking; a little is taken up from the air, and more is furnished by decaying vegetable matter. Of other substances, common salt (NaCl), Epsom salts (MgSO_4), nitrates of potassium and sodium, readily dissolve in water, and magnesium carbonate dissolves in a similar way to calcium carbonate.

The most important of these things that are taken up by the water make it what is called "hard," because they prevent the lathering of soap. Any hardness due to the presence of bicarbonate of lime, and most of that due to bicarbonate of magnesia, can be got rid of by boiling to drive away the carbonic anhydride that has made these salts soluble, and so precipitating the carbonates. The chief constituent of boiler "incrustations" and the "fur" of kettles is carbonate of lime. Hardness that can be got rid of by boiling is called "temporary hardness." The carbonate of lime can also be removed, on the large scale, by adding lime to the water, and then allowing the precipitate of carbonate of lime to settle down. This is Clark's process. The lime combines with the carbonic anhydride of the bicarbonate of lime, and changes the whole into the insoluble carbonate of lime, thus—



Hardness due to sulphate of lime and to other compounds that are not thrown out of solution by boiling is called "permanent hardness."

Water also sometimes contains organic matter taken up from decomposing animal and vegetable substances, or introduced by sewage or other drainage water that accidentally, or of set purpose, has gained access to it.

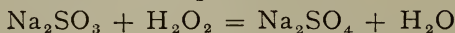
All the non-volatile impurities of water are left behind by distillation, and water so prepared is the purest that can be got in any quantity. Distilled water should be used for solutions of oxalates (ferrous oxalate developer), and for any solution containing silver. But ordinary tap water may be used even in these cases, if the injurious matters present are got rid of by adding a little of the oxalate or of the soluble silver salt, as the case may be, to the water, and allowing the precipitate formed to settle down. The action of the nitrate of silver should be allowed to take place in a glass vessel and in the light, so that organic matter may be removed, and it is well to add a little barium nitrate with the nitrate of silver, as this gets rid of sulphates, which are sometimes undesirable. The purified water should be tested, to see that an excess of the reagent is present, by adding a drop or two of a solution of calcium chloride to a small quantity of the water to which the oxalate was added, or a little common salt in the case of the nitrate of silver; if a turbidity is not produced, the water has not had enough of the reagent added to purify it.

The storage and conveyance of water needs care, for soft water attacks lead or zinc to a dangerous extent. Hard water may be kept in contact with these metals, because the sulphate and carbonate present soon form a protective coating which practically stops the solvent action; but distilled water should not be allowed to come into contact with anything but glass, good earthenware, or tin (that is, "block tin," not the "tin" of the whitesmith, which is tinned iron).

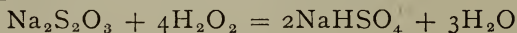
Peroxide of hydrogen is water with a double amount of oxygen (H_2O_2), and is exceedingly convenient as a source of oxygen that may be mixed with aqueous solutions, and has not the disadvantage of being acid or alkaline. It

cannot be obtained in a pure condition, unmixed with water, and the strength of commercial preparations is expressed by the number of volumes of oxygen that are liberated by boiling a unit volume of the liquid. That ordinarily sold is called ten or twenty volume.

A very dilute solution of this reagent is useful for decomposing the last traces of hyposulphite of soda, or of sulphites that may remain in a photographic film, when the minute quantities of these that cannot be washed away would be deleterious to a subsequent operation. Sulphite of soda is oxidised into sulphate, thus—

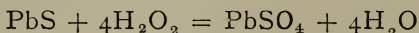


and hyposulphite into an acid sulphate thus—



the sulphates that are produced being harmless.

Oil paintings that have become discoloured or dingy through a part of the white lead having changed into sulphide of lead can be restored by the action of peroxide of hydrogen, which changes the black sulphide into the white sulphate of lead thus—



When peroxide of hydrogen is mixed with certain other substances that are oxidisers, a mutual decomposition ensues, and oxygen gas is evolved. Oxide of silver, permanganate of potassium, and black oxide of manganese are decomposed in this way. This action is exceptional.

Peroxide of hydrogen as commercially supplied has generally a slight acid reaction, for in that condition it is more stable.

Ozone is a condensed and peculiarly active form of oxygen always to be avoided as detrimental to sensitive surfaces and apparatus. It is produced by electric discharges under certain conditions, and it is well to exclude all electric apparatus from photographers' store rooms or dark rooms, except perhaps incandescent lamps, and the wires that lead to them.

CHAPTER VII.

CARBON AND SULPHUR WITH THEIR COMPOUNDS.

CARBON is one of the most unalterable of things, for it has never been melted nor volatilised, and it appears to be quite insoluble.

The diamond, which is the hardest substance known, and graphite, which is so soft that one's skin or soft paper is hard enough to act as a file upon it, are both essentially carbon. Charcoal, lampblack, soot, &c., are other less pure forms of carbon. Animal charcoal has a still greater proportion of matters that are not carbon, and is obtained by heating bones or animal refuse with exclusion of air. It is variously known as bone black, animal black, ivory black, &c.

These various forms of carbon have many uses. An uncut diamond, conveniently mounted so that one of its edges projects, forms the usual instrument for cutting glass. A fragment of a diamond mounted, with a sharp corner projecting, is useful for scratching or writing upon glass.

Graphite is commonly called "blacklead," and everyone is familiar with its use in coating (blackleading) iron work, and in pencils. Amorphous carbon has a more extended application as a pigment. Ground up with diluted negative varnish it may be applied to almost any surface to give a coherent, dull black coating, and by re-varnishing with uncoloured varnish, a brilliant black surface is obtained. Metal articles are preferably warmed before treatment. Starch-paste may be used instead of varnish for blackening the insides of cameras. The tinctorial matter of ordinary printers' ink is lampblack. In carbon printing, too, carbon is used, and as nothing is less amenable to change we may regard it as permanent. It is, however, customary to modify the tint by adding other pigments which may not be so permanent.

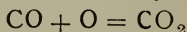
Lampblack is the commonest form of amorphous carbon. It is prepared by burning pitch or resin in such manner as to produce much soot. There is always more or less of oily matter that condenses with the lampblack. Its presence is not generally harmful, but it can be got rid of by heating the black to a red heat in a covered vessel.

It is stated that the soot from an ordinary gas flame is grey; that that got from the tip of a benzene flame is brown; and that bone black is the blackest of these forms of carbon.

Animal charcoal is an efficient and innocuous decolouriser, useful especially in bleaching lac varnishes, for it is not safe to employ lac bleached in the ordinary commercial way lest it should be contaminated with the acid used.

Carbon combines with oxygen in two proportions, forming carbonic oxide (CO) and carbonic anhydride (CO₂).

Carbonic oxide is produced when ordinary fuel burns with an insufficient supply of air, as is often the case in close stoves. It is a combustible gas that burns with a blue flame producing carbonic anhydride.

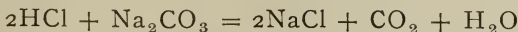


Carbonic oxide is highly poisonous.

Carbonic anhydride (CO₂) is the product of the complete combustion of carbon, and is not poisonous in the ordinarily accepted sense of the word, but is, on the contrary, very essential to our well-being. An undue accumulation of this, as of any other gas, is injurious, and should be guarded against by good ventilation. The unpolluted air contains about 4 parts of carbonic anhydride in 10,000 volumes, and respired air from 3½ to 4 per cent. It is produced by the combustion of carbon, respiration, fermentation, decay, or by the action of an acid upon a carbonate.

An acid and a carbonate cannot exist side by side; they will always react together with effervescence, because of the liberation of the gas under consideration. The base of the carbonate forms its corresponding salt with the acid used; for example, hydrochloric acid and sodium car-

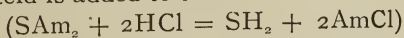
bonate produce sodium chloride, carbonic anhydride, and water, thus—



Carbonic anhydride is soluble in an equal bulk of water. When dissolved in water it has the chemical properties of an acid, though of a very weak acid. Ordinary soda water is little more than a solution of carbonic anhydride in water under pressure, and the taste of it does not even remind one of an acid, though it can turn blue litmus paper half-way towards red. It combines eagerly with caustic alkalies, not neutralising them, but reducing their caustic nature. It is an active agent in the rusting of iron, and polished steel will remain untarnished for years in an atmosphere, however moist, if carefully freed from carbonic anhydride and other acid substances.

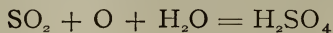
The compounds that sulphur enters into are among the most useful that the photographer has at his disposal, and it is only by those who are ignorant of the facts of the case that this element is invariably viewed as an enemy. It occurs widely distributed in the free state, in combination with metals, and in many other compounds, of which both albumen and gelatine are examples.

Sulphur itself is a yellow brittle solid which burns without difficulty, and is of no immediate use to photographers. Its compound with hydrogen, sulphuretted hydrogen (SH_2), is occasionally useful, but must be rigorously excluded from any apartment where sensitive material is stored, and from albumen silver prints either in a finished condition or at any stage of production. The ordinary silver print when subjected to the influence of this gas rapidly fades to the yellow colour that is so familiar. The sulphides of sodium, potassium, and ammonium give off sulphuretted hydrogen copiously when any acid is added to them



and are decomposed slowly by exposure to the air. These reagents should therefore be carefully guarded. The characteristic odour of rotten eggs, that is, decomposing albumen, is due to sulphuretted hydrogen.

When sulphur burns it produces sulphurous anhydride (SO_2), a heavy gas with an odour that was better known when matches were tipped with sulphur. Water dissolves about forty times its volume of sulphurous anhydride, and gives a liquid that has acid properties. This solution is referred to when sulphurous acid is prescribed for developers. It is one of the most uncertain of preparations, varying in strength as at first obtained, and rapidly changing afterwards—not merely getting weaker by the loss of some of the dissolved gas, but absorbing oxygen from the air and becoming sulphuric acid, thus—



The comparative amounts of sulphuric acid in two or more samples of sulphurous acid may be roughly estimated by taking a small quantity of each sample, adding to each, with agitation to thoroughly mix an equal quantity of hydrochloric acid, about twenty times as much water, and a solution of barium chloride in small quantity, but until the maximum turbidity is produced. The turbidity is proportional to the amount of sulphuric acid present. The mixture so prepared that has the strongest smell of burning sulphur may be considered to indicate that the sample of sulphurous acid it was made from is the strongest.

Sulphurous anhydride can easily be liquefied by cooling it with ice and salt. It can be obtained commercially in "syphons," somewhat similar to those used for aerated waters, and this is by far the most convenient and certain way to get this compound and the preparations obtainable from it. It would, however, be very unsafe for anyone not accustomed to chemical operations to have to deal with liquefied sulphurous anhydride.

CHAPTER VIII.

SULPHURIC, HYDROCHLORIC, AND NITRIC ACIDS.

SULPHURIC acid is the most stable of the compounds of sulphur. It is produced in a dilute form by the spontaneous oxidation of sulphurous acid as already noted, and a similar method of preparation is pursued commercially. Sulphurous anhydride, got by burning sulphur, is mixed with air, steam, and a small proportion of nitric acid fumes in a large leaden chamber, with a shallow layer of water upon its floor. The sulphurous anhydride, steam, and oxygen of the air combine according to the above equation to produce sulphuric acid, and the action is made rapid by the nitric acid, which readily gives up some of its oxygen, leaving a lower oxide of nitrogen. The nitric oxide resulting has the property of spontaneously combining with the oxygen of the air, and of at once parting with the oxygen it has combined with to the sulphurous anhydride and water, re-forming nitric oxide, which reacts again, and so continuously. One charge of nitric acid fumes would thus be sufficient for preparing any quantity of sulphuric acid if loss could be altogether avoided. The weak acid produced in the chambers is concentrated in leaden pans, and then in glass or platinum vessels as far as possible, to produce the "oil of vitriol" of commerce.

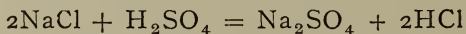
The photographer should always use the sulphuric acid known as "pure," and if this is obtained from a respectable firm it may be relied upon. It should be colourless; a slight brown tint is probably due to a little dust. It must be kept in a properly-stoppered bottle, for it rapidly takes up any moisture from the air that gets to it. It is a more powerful drying agent than chloride of calcium, but, being a liquid and highly corrosive, it is not so convenient. The strong acid rapidly chars wood, paper, &c., and, as it is not

volatile, it is dangerous to use it for clearing prints, &c., unless its application is followed by a thorough washing. Any dilute acid left in the paper remains; it keeps itself dilute because of its eagerness to combine with water, but its charring power is brought into play when it is concentrated by a gentle heat. A secret ink that was sold some time since was nothing whatever but very weak sulphuric acid, and the writing was made visible by warming until the acid blackened the paper. Parchmentised paper, or vegetable parchment, is made by plunging unsized paper into sulphuric acid mixed with a little water, and, after a few seconds, washing it thoroughly. It is stated that finished silver prints may be treated in this way without any injury to the picture.

It is necessary to exercise great care when diluting strong sulphuric acid, because of the violence of the combination of the two substances resulting in a considerable rise of temperature. If water is put into sulphuric acid the heating effect will be so great as to boil the water, if it does not produce a spluttering that is almost equivalent to an explosion. Hence the acid should always be poured into the water in a thin stream, and the liquids should be kept gently agitated the whole time with a rod of glass. If a white turbidity is produced by the dilution, the acid used is not pure, but contains sulphate of lead derived from the vessels used in its manufacture.

Dilute sulphuric acid acts readily upon zinc and iron, and the hot strong acid corrodes all the ordinary metals; gold is not affected by it. Sulphuric acid is used in the preparation of hydrochloric, nitric, acetic, formic, oxalic, and citric acids, alum, corrosive sublimate, and many other common chemicals.

Hydrochloric acid (HCl) is prepared by warming together common salt and strong sulphuric acid.



The hydrochloric acid escapes as a colourless gas, and is conducted into water to form the solution that is sold as "spirits of salts," "muriatic acid," or "hydrochloric acid." This solution fumes when exposed to the air, and

contains generally about 30 per cent. of real acid, and never more than 40 per cent. It is made weaker by heating, it rapidly volatilises at the temperature of boiling water, and has practically no charring effect upon wood or paper. It is therefore a safer acid to use than sulphuric for preventing stains on gelatine films, etc. Dilute hydrochloric acid acts in the same way as dilute sulphuric acid in the majority of cases.

The hydrochloric acid used for photographic purposes should be what is known commercially as pure. It must be stored in a glass stoppered bottle, and should not be continually kept in a very light place, because light decomposes it slowly and gives free chlorine. The pure commercial acid is colourless. A yellow sample may owe its colour to iron, organic matter, or chlorine, and is unsafe to use except by one who has sufficient chemical knowledge to discover the cause of the colour, and to recognise its effect in any particular case.

Nitric acid (also called "aqua fortis," HNO_3) is prepared by the action of strong sulphuric acid upon potassium or sodium nitrate, and is a liquid. The strongest commercially obtainable has a specific gravity of about 1.5, but what is understood as strong nitric acid has a considerably less specific gravity, and contains at least some thirty per cent. of water. Nitric acid is very easily decomposed, giving up a part of its oxygen, the deoxidised residue of the acid showing as reddish fumes; it is, therefore, generally inferior to hydrochloric acid except for purpose of oxidation, and where soluble silver salts are concerned (hydrochloric acid would form the insoluble chloride of silver). When mixed with about four times its volume of hydrochloric acid, aqua regia is formed, which has the power of dissolving gold and platinum. The active agent of aqua regia is the chlorine liberated from the hydrochloric acid by the oxygen of the nitric acid.



Nitric acid acts upon most of the common metals, their oxides, hydrates or carbonates, including silver, producing nitrates; and its action upon the various forms of cellulose,

such as cotton-wool and paper, is perfectly analogous. Pyroxylin or gun-cotton is a nitrate of cellulose, or a mixture of cellulose nitrates, and collodion is a solution of it in a mixture of alcohol and ether.

Nitric acid fumes when exposed to the air. It is colourless and pure, and has a very sharp, penetrating and choking odour, something like hydrochloric acid. It should be free from hydrochloric acid, especially when it is to be used for preparing nitrate of silver, and this can be sufficiently proved by adding a little of the acid to four or five times its bulk of water, and then mixing with it a drop or two of nitrate of silver solution. If no turbidity is produced, hydrochloric acid is absent.

CHAPTER IX.

THE PRINCIPAL COMPOUNDS OF POTASSIUM, SODIUM AND AMMONIUM.

IN reviewing the chemistry of the metals and their salts from a photographic point of view as concisely as possible, it will be convenient to consider the two alkali metals, potassium and sodium, and the compounds of ammonium, simultaneously. Although potassium and sodium in the isolated form as metals have no practical interest to the photographer, one point about them is worth noticing, because it gives the key to differences in the effects of their compounds. Both metals decompose water when thrown upon it, and liberate hydrogen; but potassium acts with so much more energy than sodium, that the liberated gas is ignited. On referring to the tables of atomic weights and valency, it will be seen that thirty-nine parts by weight of potassium are required to do the same amount of work in forming compounds, or to occupy the same place as twenty-three parts by weight of sodium. Weight for weight, therefore, the former metal has less power than the latter, but it exerts its power with more intensity. A similar difference may often be traced in the compounds of these metals.

Potassium and sodium compounds are not volatile up to a red heat. Some are decomposed by heating, but the metals always remain in the residue. Ammonium compounds, on the other hand, are always either volatilised or decomposed by heating them to a lower temperature than redness; the ammonia is always driven off. Hence ammonia used to be called the "volatile alkali."

The hydrates of potassium (KOH), sodium (NaOH), and ammonium (AmOH), are commonly called caustic potash, caustic soda, and ammonia respectively; and

their caustic nature is shown by the rapidity with which they will disintegrate one's skin. The carbonates used to be called the "mild" alkalies, to distinguish them from the caustic alkalies, and the old name very well describes the difference between them. Caustic potash and soda cannot be purchased pure because there is no ready means of separating foreign matter from them, and they absorb acid vapours of any description with great avidity. They dissolve grease, and hence are useful as detergents, but as they have a very decided action upon glass, they should be avoided or used sparingly for cleaning plates. Ammonia mixed with alcohol would appear to be preferable if we merely regard the preservation of the surface of the glass.

Ammonia as purchased is a solution of gaseous ammonia (NH_3) in water. The specific gravity of the solution gets less as the amount of ammonia increases, and the ordinary full strength solution has a specific gravity of .880. It is advisable to dilute this with an equal bulk of water as soon as possible, as the more dilute solution loses ammonia less rapidly. The solution of ammonia absorbs carbonic acid from the air, but much more slowly than caustic potash or soda.

The carbonates of potassium and sodium are easily obtained pure, and are both crystallisable. The crystals contain water in very different proportions, but the dry salts can be purchased. "Washing soda" is crystallised sodium carbonate ($\text{Na}_2\text{CO}_3, 10\text{H}_2\text{O}$); it contains nearly two-thirds of its weight of water, and by exposure to the air loses some of its water and becomes opaque. It should be noted that carbonate of sodium is commonly called "soda," and that what is generally sold by retail druggists as "carbonate of soda" (for medicinal purposes, putting in the teapot, etc.) is the bicarbonate, and useless as a substitute for the other. Carbonate of potassium when crystallised contains about one-fifth its weight of water ($\text{K}_2\text{CO}_3, 2\text{H}_2\text{O}$), and by exposure to the air absorbs water, eventually getting pasty and wet. In all formulæ where either of these carbonates is specified, it should be clearly stated whether the crystallised or dry salt

is intended. Without this the formula is practically useless.

Carbonate of ammonium is prepared in hard, irregular lumps, which smell strongly of ammonia and lose ammonia on keeping, leaving an opaque powder of bicarbonate. When this salt is to be used, the loose powder should be scraped off the lumps, and only the hard semi-transparent part taken.

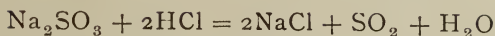
Chloride of sodium (NaCl), also called common salt or table salt, is not pure unless specially prepared. If it has a tendency to get moist and clot together, it contains magnesium chloride. Potassium chloride (KCl) is very similar to sodium chloride in its appearance and chemical behaviour. Ammonium chloride (AmCl), also called muriate of ammonia or sal-ammoniac, is more extensively used than either of the other chlorides. It is readily distinguished from them, as it gives off dense fumes when heated, and, if pure, it is entirely vaporised below a red heat. By sublimation it is freed from non-volatile impurities, and therefore the commercial salt is generally more pure than the chlorides of sodium or potassium.

Bromide of potassium (KBr) is less liable to change than bromide of ammonium (AmBr), and is to be preferred on this account. Weight for weight, however, the potassium salt does not appear to be so powerful a restrainer as the other. Molecular proportions of each have perhaps equal restraining power, in which case five grains of ammonium bromide would be equivalent to practically six grains of potassium bromide. This proportion must also be observed if one of the bromides is substituted for the other in preparing an emulsion. These salts are very soluble in water, and a forty per cent. or even a stronger solution is easily obtained.

Iodide of potassium (KI) should be quite white and dry, otherwise it is safer to reject it. By exposure to the air it is decomposed with liberation of iodine which colours it brown, and carbonate of potassium is formed which absorbs moisture and makes the salt wet. Free iodine gives an intense blue colour when it is mixed, even in

minute quantity, with cold starch-paste. Starch-paste is prepared by pouring boiling water on to a thin mixture of starch and cold water, until the starch loses its milk-white colour. A sample of iodide of potassium should be quite white and dry, and it should give no blue colour when dissolved and mixed with starch paste and a few drops of dilute sulphuric or acetic acid. Iodine dissolves copiously in an aqueous solution of iodide of potassium, giving a dark brown solution. This is generally a more convenient preparation to use than the tincture, when a solution of iodine is required, as for intensification, decomposing the last traces of hyposulphite of soda in prints, &c.

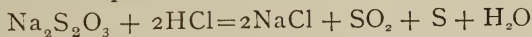
Sodium sulphite ($\text{Na}_2\text{SO}_3 \cdot 7\text{H}_2\text{O}$) is best prepared from sodium carbonate and sulphurous anhydride. It is convenient to take dry sodium carbonate and dissolve it in five times its weight of water, and to pass a current of sulphurous anhydride into the boiling solution until a drop withdrawn from the solution shows a slight acid reaction to phenol-phthalein. The solution contains about 50 per cent. of the salt, and should be stored in little bottles filled to the neck, and corked with sound corks which are subsequently waxed. If such a solution is prepared and preserved with proper care it will have the advantage of purity, but this salt can now be obtained in excellent condition. It would be useless for the photographer who is not accustomed to chemical operations to attempt to prepare his own sulphite; he must buy the solid salt, and take care that the lumps are perfectly clean looking, and show no signs of changing to a white powder. Samples may be compared by dissolving half a dram in an ounce of water, and thoroughly mixing with it about one dram of hydrochloric acid, and then a strong solution of barium chloride, until the maximum turbidity is produced (or two grammes of the sample to 30 c.c. of water and 5 c.c. of hydrochloric acid may be taken). The turbidity is due to sulphate of sodium, therefore the less of it the better; and the acid added liberates sulphurous anhydride which has the characteristic odour of burning sulphur, by its action upon the sulphite, and the best sample will therefore give the strongest odour. The action of the acid is thus expressed—



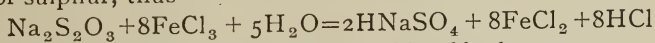
If the solid salt is to be used, it may be dissolved in water to form a 50 per cent. solution, and it should then have a few bubbles of sulphurous acid gas passed through it until it reacts acid to phenol-phthalein. Litmus paper is not of use in this case. The photographer who has not the means of acidifying his sulphite in this manner may add three drops of concentrated hydrochloric acid or two or three grains of citric acid to each two ounces of solid salt in solution (or three grammes of acid to 1,000 grammes of the salt). The sulphite should not be acidified with sulphuric acid if it is to be employed in the developer, as the sulphate of sodium produced retards development in a very unsatisfactory manner.

Sodium sulphite deteriorates when exposed to the air by absorbing oxygen and forming sulphate. The sulphate of soda, though worse than useless in the developer, does no harm when the partially oxidised sulphite is used as a follower to mercuric chloride in intensification.

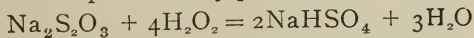
Sodium hyposulphite ($\text{Na}_2\text{SO}_3 \cdot 5\text{H}_2\text{O}$), also called sodium thiosulphate, is more stable than the sulphite. A solution of it should not be used until a day or so after it is made up, to allow a little sulphur that is generally liberated to deposit itself. Sodium hyposulphite, if clean, may be relied upon. It is decomposed by acids and by alum with production of sulphurous anhydride and precipitation of sulphur, thus—



and by ferric chloride or peroxide of hydrogen or sodium hypochlorite it is oxidised to sulphate without precipitation of sulphur, thus—



Less acid is produced by peroxide of hydrogen—

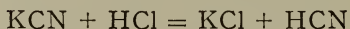


but the amount of acid resulting in any case is so small as to be negligible, when only traces of hyposulphite of soda are got rid of in this way. If any acid or alum is mixed with a solution of hyposulphite of soda, as some recommend

in making a fixing bath, a part of the salt is decomposed, and the fixing power of the solution is therefore decreased.

The sulphides of potassium, sodium, and ammonium are of little photographic use; they are employed, though seldom, in intensification. In any form they give off sulphuretted hydrogen as air gains access to them, and as this gas is exceedingly harmful to sensitive surfaces, the sulphides should be rigidly excluded from the general photographic operating room. These compounds change by oxidation, and an old sample will probably have no sulphide remaining in it. If fit for use, the smell of rotten eggs is evolved when any acid is added to it.

Potassium cyanide (KCN) is a white salt that may be got in crystals, but is generally sold in irregular lumps or in sticks. It is exceedingly poisonous, and any acid will decompose it with evolution of hydrocyanic (or prussic) acid, thus—



The salt as purchased is never pure; it contains as much as three-quarters of its weight of potassium carbonate, but this is not detrimental. If white and clean and dry it may be considered fit for use.

Ferrocyanide of potassium ($\text{K}_4\text{FeC}_6\text{N}_6, 3\text{H}_2\text{O}$), or yellow prussiate of potash, is of very little importance photographically, but the ferricyanide of potassium ($\text{K}_3\text{FeC}_6\text{N}_6$), or red prussiate of potash, is an active agent in the production of "blue prints," and is useful as a reducer of negatives. The ferricyanide is not stable in solution, especially when exposed to light; it should therefore be dissolved only as it is wanted. The crystals are invariably covered with a loose powder or coating of the partially decomposed salt, but this is easily removed by washing with water until they appear of a bright ruby red colour.

Potassium oxalate ($\text{K}_2\text{C}_2\text{O}_4, \text{H}_2\text{O}$) is distinguished from other oxalates of potassium which are acid by calling it neutral, although it has an alkaline reaction. The salt dissolves in about three times its weight of water even in the cold, and for most purposes for which it is used—certainly for the ferrous oxalate developer—it should have just enough

oxalic acid added to it to give the solution a slight acid reaction. For making a solution of this salt distilled water should be employed; or, if hard water is used, the oxalate of lime produced from the lime salts present will need either to be filtered off or to be allowed to settle down.

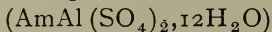
CHAPTER X.

VARIOUS INORGANIC COMPOUNDS.

CALCIUM chloride (CaCl_2) is used chiefly for drying purposes, as in the canisters made for preserving platinum or other sensitive paper in. The commonest preparation that is usually sold is good enough for this purpose, and when it begins to lose its desiccating power it only needs heating nearly to redness to make it useful again, because the moisture, in attaching itself to the chloride of calcium, effects no chemical change in the compound, and is driven off at the higher temperature. A tin, copper, or thin iron dish, heated over a gas stove or a clear fire, is a convenient apparatus to use for this purpose.

Bleaching powder, or chloride of lime, sometimes incorrectly called calcium hypochlorite, is prepared by passing chlorine over slaked lime. It decomposes in a variety of ways by keeping, and an old or moist sample should be rejected. Its use in photography is due to the chlorine that it contains in an easily available form, and any acid, even carbonic acid, will liberate chlorine from it.

Alum is a double sulphate of aluminium and ammonium.



It is soluble in about eighteen parts of cold water, it has a strong acid reaction to litmus, and, indeed, acts generally like an acid, except that it hardens gelatine. It is preferable to buy the crystallised compound, as the powdered salt is difficult to dissolve.

Ferrous sulphate (also called green vitriol or copperas, $\text{FeSO}_4, 7\text{H}_2\text{O}$) forms green crystals, which, when fairly pure and clean, are remarkably permanent. Ten to fifteen years' preservation in a corked bottle will not appreciably affect them. This salt should be dissolved in cold water, twice its weight of water is sufficient, as heating with water causes a partial decomposition unless an acid is

previously added. The solution is oxidised and so rendered useless by exposure to the air, with the formation of a rusty coloured precipitate. If an acid or an alkaline citrate has been added the oxidation will take place, but no precipitate will fall.

The double sulphate of iron and ammonium ($\text{FeAm}_2\text{S}_2\text{O}_8, 6\text{H}_2\text{O}$) gives a solution that is perhaps more permanent than that of the simple ferrous sulphate, and is preferred by many as a developer for wet collodion plates.

Ferric chloride (FeCl_3), or perchloride of iron, is generally bought in solution. Strong solutions are reddish brown, and a well marked yellow colour remains after adding a very large proportion of water. A solution that contains free hydrochloric acid has a lighter colour.

If a solution of ferrous sulphate is mixed with a solution of oxalic acid and warmed, a copious yellow precipitate of ferrous oxalate (FeC_2O_4) forms. This compound is practically insoluble in water, and soluble in alkaline oxalates. Potassium oxalate is preferred as a solvent, because a saturated solution of it dissolves more of the ferrous salt than either of the other oxalates. Ferrous oxalate, however, is more often made only as it is required, by mixing a solution of ferrous sulphate with a solution of potassium oxalate. A solution of this salt in an alkaline oxalate has a well marked red colour.

Ferric oxalate ($\text{Fe}_2(\text{C}_2\text{O}_4)_3$) is also sparingly soluble in water, but cannot be conveniently prepared by precipitation as it dissolves in acids. Like ferrous oxalate, it is never used alone, but always as a double compound, its second constituent being generally oxalic acid, though an alkaline oxalate might be used instead. Ferric oxalate as commercially obtained is a solution of the salt in oxalic acid. It may be prepared by adding ammonia to a hot and rather dilute solution of ferric chloride, thoroughly washing the precipitated hydrate of iron and then draining it as dry as possible. Finely-powdered oxalic acid is then put upon the gelatinous mass in small quantity at a time with vigorous shaking until after several hours almost the whole of it is dissolved; and the solution is then filtered. The preparation should be protected from the

light as soon as the oxalic acid is being added. Ferric oxalate is the sensitive salt in paper prepared for the platinum printing process.

The double citrate of iron and ammonium is obtained from washed ferric hydrate prepared as above described. The amount of citric acid added to nearly dissolve the iron compound must be known; an equal amount is taken, neutralised with ammonia, and then added to the iron solution. This double salt is chiefly used in preparing the paper that gives prints in Prussian blue.

Permanganate of potassium (KMnO_4) is obtained in small crystals of a dark purple brown colour, and is distinguished by its exceptionally great tinctorial power. A scarcely weighable amount will give a fine purple colour to a pint or quart of water. Reducing agents, such as hyposulphite of soda, either change it to the green manganate, or, if they are added in excess, to colourless compounds of potassium and manganese. A solution of this salt stains paper and such substances to a brown colour, because the permanganate gives up some of its oxygen to the organic matter, and forms brown coloured manganese compounds. Hence it is used to intensify gelatine transparencies obtained as in carbon printing. The brown colour so produced is readily removed by a solution of sulphurous acid.

Chrome alum is a dark violet coloured substance, similar in chemical constitution to common alum, being a double sulphate of chromium and potassium ($\text{KCrS}_2\text{O}_8, 12\text{H}_2\text{O}$). It is very effective in rendering gelatine insoluble, and a small proportion is sometimes added to gelatine preparations to confer the desirable amount of hardness.

Bichromate of potassium ($\text{K}_2\text{Cr}_2\text{O}_7$) and bichromate of ammonium ($\text{Am}_2\text{Cr}_2\text{O}_7$) are red salts, and one or the other is used in almost all the photo-mechanical processes and in carbon printing, as well as in other photographic operations. The use of the bichromates is founded on the facts that when a gelatine film is impregnated with one of them and exposed to light the chromate is reduced to compounds analogous in effect to chrome alum, and thereby the gelatine

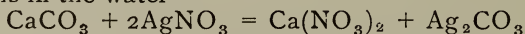
is changed so that it is insoluble in hot water, and will not swell up in cold. Soluble compounds of chromium are poisonous, and especially injurious to some constitutions, causing great irritation, and even soreness of the skin. These and worse effects may result from the continued application of solutions to the skin, as in carbon printing, if the operator is sensitive, as some are; but great care should be taken by everyone that the smallest sore place is protected from contact with any chromate.

Coppersulphate ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$), leadacetate ($\text{PbC}_4\text{H}_6\text{O}_4 \cdot 3\text{H}_2\text{O}$), and lead nitrate (PbN_2O_6) are comparatively unimportant to the photographer, and the commercial preparations are invariably suitable when they are required.

Silver is a white metal. It is an interesting coincidence that this metal, which is the best known conductor of heat and electricity, forms compounds which are the most usefully acted upon by light. Many metallic compounds are decomposed by exposure to light, but it appears that silver alone gives compounds that are affected by an exceedingly small amount of light in such a way that a reducing agent (or developer) is enabled thereby to cause a complete decomposition of the salt used.

Nitrate of silver (AgNO_3) is the one soluble salt of silver, and it is consequently the starting point in the production of silver compounds in general. It forms heavy, colourless crystals, which contain no water of crystallisation. A crystal, if placed upon wet litmus paper, ought to redden it very slowly indeed, if at all, for actually pure nitrate of silver appears to be more inclined to show a slight alkaline reaction. To fit the compound for photographic uses it is generally re-crystallised two or three times, but the amount of purification effected by re-crystallisation depends entirely upon the care with which the operation is performed, and a slight improvement secured in this way may be soon negated by careless treatment afterwards. The small differences in various preparations cannot be detected in any rough and ready manner; indeed, it appears probable that the photographic fitness of a sample of silver nitrate is a more delicate indicator of its purity than any chemical test. Distilled water should

always be used in making solutions of this salt, but if the only water that can be obtained is impure, whether it is called distilled or not, it may in the majority of cases be made serviceable by adding a small quantity of nitrate of silver to it in a clean white glass bottle, and exposing it to sunlight until the insoluble matter produced has settled down, and the supernatant water is quite clear. The nitrate of silver precipitates, or otherwise gets rid of those matters that are injurious to it, and the clear water may be poured off. Such purification, however, is comparative, and not absolute. If, for instance, the water is hard from the presence of carbonate of lime, then an insoluble carbonate of silver is precipitated, but nitrate of calcium remains in the water—



and the nitrate of calcium, although it will not interfere with the nitrate of silver, may be more or less detrimental to the preparation that the nitrate of silver solution is required for. The following are the changes that nitrate of silver undergoes when its solution is mixed with the solution of various reagents:—

Hydrochloric acid or soluble chlorides produce a white curdy precipitate of chloride of silver (AgCl), which is soluble in ammonia, but unaffected by nitric acid.

Bromide of potassium (KBr) or other soluble bromides give a yellowish white precipitate of silver bromide (AgBr), soluble in strong ammonia, but not in weak, and insoluble in nitric acid.

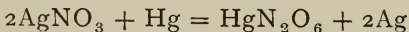
Iodide of potassium (KI) or other soluble iodides give a light yellow precipitate of silver iodide (AgI), insoluble in ammonia or nitric acid.

Carbonate of sodium (Na_2CO_3) or of potassium gives a grey precipitate of carbonate of silver (Ag_2CO_3), which is soluble in nitric acid with effervescence, reproducing silver nitrate.

Caustic soda (NaOH) or caustic potash (KOH) gives a brown precipitate of oxide of silver (Ag_2O), which is soluble in either nitric acid or ammonia.

Ammonia gives a precipitate of silver oxide which dissolves if more ammonia is added.

Mercury, zinc, tin, iron, copper, lead, and other metals act upon nitrate of silver solution, and precipitate the silver in the metallic form. The metal used is at the same time corroded, and an equivalent weight of it is dissolved, thus—



Nitrate of silver may be heated in the solid condition until it melts without decomposition; but if any organic particles, such as dust, are allowed to gain access to it, the salt gives oxygen to the organic matter, and is itself partially reduced to nitrite of silver (AgNO_2). The pure nitrate will lose oxygen and become nitrite if it is heated far above its fusing point. The nitrite of silver shows itself in making a solution of the fused salt by remaining as a difficultly soluble powder, and the alkaline reaction of the solution is a further demonstration of its presence.

The only compound of mercury that is much used by the photographer is mercuric chloride (HgCl_2), or corrosive sublimate. It is a white, very heavy compound, soluble in about fourteen times its weight of cold water, and more soluble in the presence of ammonium chloride. The commercial preparations are generally in suitable condition for use.

Uranium nitrate $[(\text{UO}) \text{N}_2\text{O}_6]$ and the corresponding acetate are yellow crystalline salts that do not call for any special remarks.

Chloride of gold (AuCl_3) is a compound often talked about, but rarely seen. It is probable that the preparations that appear to be the cheapest are really the most expensive if the actual amount of metal is made the basis of the cost, and this is the only correct method of calculating the matter, as the gold itself is the only valuable and useful constituent. By dissolving gold in aqua regia, and evaporating and crystallising, the chloride of gold is obtained in combination with hydrochloric acid and water as yellow deliquescent crystals. This is the only commercial preparation that can with any propriety be called simply "chloride of gold." If common salt is added to the solution before crystallisation, the sodium chloride takes the place of the hydrochloric acid, and a

compound is obtained of chloride of gold, chloride of sodium and water. This preparation is the "non-deliquescent chloride of gold," and as it is more stable and not acid, it is probably more suitable for photographic uses. In no case, however, is the weight of the commercial gold salts an exact criterion of its value, but the weight of the actual gold itself.

Potassium platinous chloride, or potassium chloroplatinite (K_2PtCl_4), is a red crystalline salt easily soluble in water. It is obtained by reducing a solution of platinic chloride by means of sulphurous acid gas and adding the required amount of potassium chloride. The crystals are obtained on evaporating the solution. This salt is used for platinum printing and for toning silver prints. For these purposes platinous chloride ($PtCl_2$) is preferred to platinic chloride ($PtCl_4$), because in depositing the metal there is less chlorine to be removed from it, and also because the withdrawal of chlorine from platinic chloride may result merely in the formation of platinous chloride with no deposit of metal. It is impossible to take any chlorine from the lower chloride without getting a corresponding amount of metal liberated. Platinous chloride is used in combination with potassium chloride because by itself it is insoluble in water.

CHAPTER XI.

VARIOUS ORGANIC COMPOUNDS.

IF a bone is soaked in dilute hydrochloric acid for a few days the mineral matter, which is chiefly phosphate of lime, will be dissolved away. The bone will appear much the same as before, but instead of being hard it will be tough and soft while still wet. The substance that remains is the organic part of the bone, and is called "ossein." When ossein is boiled in water it does not suffer an appreciable change in composition, but it gradually becomes soluble, and the solution obtained sets to a jelly as it cools. This product is gelatine. Skin and hide also give gelatine when boiled with water, but unossified cartilage yields a jelly which has different properties, and is called "chondrin." Chondrin is present to a considerable extent in "size"; it is less adhesive than gelatine, and also differs from it in being made insoluble by nearly all acids, by alum and by iron salts, but not by corrosive sublimate. It is present in varying quantities in commercial gelatine, and to the least extent in those specially prepared for photographic purposes.

Isinglass is a variety of gelatine prepared principally from the swimming bladder of the sturgeon. Glue is an impure gelatine made from animal offal. The purer sorts of gelatine are prepared from selected materials, after they have been subjected to a prolonged cleaning process by means of alkali and sulphurous acid, by extracting them with steam, allowing undissolved matter to settle out of the solution, cooling to gelatinise, and thoroughly washing the jelly to remove the acid. It is then re-melted, and worked into the desired form for drying.

Gelatine varies even from similar tissues of animals of different ages, and it also varies according to the treatment that the raw material has undergone in its prepara-

tion. The chemical composition has been found by different analysts who have experimented upon gelatine obtained from different sources to be about as follows in parts per hundred:—

Carbon	..	..	..	..	49 to 50
Hydrogen	..	..	..	..	6·5 to 7
Nitrogen	..	..	..	..	17·5 to 18·5
Sulphur	..	..	..	..	·1 to ·2 or more
Oxygen	..	..	..	..	24 to 27

Gelatine should be colourless, transparent, hard when dry, inodorous, and when in solution tasteless, and neither acid nor alkaline. It sinks in water. When heated it melts and decomposes, giving off ammoniacal fumes, like most nitrogenous substances of animal origin, and when burnt away should not leave more than one to two per cent. of ash. If placed in cold water it swells very considerably, and absorbs from five to ten times its weight of water without appreciably dissolving. The swelled gelatine dissolves in hot water, and if the water used is not more than one hundred times the weight of the gelatine the solution will gelatinise on cooling; but with 150 parts of water to one of gelatine the solution will remain liquid. By prolonged heating of the water solution, as in cooking emulsions, it gradually loses its gelatinising qualities, and the change takes place more quickly at a high than at a low temperature; but alcohol will precipitate from such a solution gelatine that will gelatinise when boiled with fresh water.

Strong sulphuric acid or nitric acid changes gelatine into entirely different substances which are readily soluble; hydrochloric acid that is not too weak dissolves gelatine; acetic acid causes it to swell up, makes it soft and transparent, and finally dissolves it. The acetic acid solution, though it does not gelatinise, retains the adhesive qualities of the gelatine, and is the foundation of some makes of "liquid glue." Slightly diluted nitric acid acts in a somewhat similar way to acetic acid. Dilute acids in general neither prevent the gelatinisation of gelatine, nor make it insoluble; nor do dilute alkalies, or even strong ammonia.

Moist gelatine exposed to the air decomposes, becom-

ing first acid, and then alkaline from the production of ammonia. The development of an acid reaction is characteristic of gelatine, and acidity in a sample may indicate that putrefaction has begun, or, on the other hand, that the acid used in the preparation of the article has not been thoroughly washed out. At a temperature of 90° Fah. the decomposition of moist gelatine may begin in twenty-four hours, but gelatine appears to remain unchanged if it is carefully kept dry.

Soluble gold and silver salts do not make gelatine insoluble, and such mixtures are readily acted upon by light. Nitrate of silver with gelatine is reduced on exposure, with formation of red-coloured products. Tannic acid ("tannin") gives a very insoluble compound with gelatine, and this reaction is so delicate, that a solution containing so little as one part of gelatine in five thousand parts of water is rendered turbid by the addition of tannic acid. The tanning of skins in making leather consists essentially in causing the tanning material used to act upon the gelatine in the hide and change it into this insoluble compound, which is distinguished for its toughness and non-liability to putrefy. But if tannic acid is applied to a gelatine negative it causes rapid frilling and blistering, unless the solution used is very weak.

Corrosive sublimate, platinic chloride, chrome alum and chlorine gas make gelatine insoluble, and alcohol also precipitates it from aqueous solutions. Gelatine that has been soaked to swell in a solution of chrome alum will not dissolve, though the water it is put in is raised to the boiling temperature. Bromine and iodine combine with gelatine without rendering it insoluble. Ordinary alum raises the temperature at which it dissolves. Alum, alcohol, carbolic acid, salicylic acid, chloral, thymol or zinc salts, in small quantities, or glycerine in considerable quantities, retard or prevent the putrefaction of gelatine.

Albumen is, like gelatine, extensively employed in photography as a medium for sensitive salts. It is preferably obtained from the whites of eggs, which contain about 12 per cent.; for though blood is a cheaper material and contains some 7 per cent., its albumen is not so readily got

in an equally pure condition. Albumen from different sources does not appear to have exactly the same properties. It contains about $1\frac{1}{2}$ per cent. of sulphur, which is readily changed into sulphuretted hydrogen by putrefaction, or by a few minutes' boiling with a weak caustic alkali. Albumen differs entirely from gelatine in being precipitated or made insoluble (coagulated) by heating its solution to a little above 60° C., by the action of dilute acids, or of a solution of nitrate of silver. It is insoluble in alcohol, and weak alcohol added to its solution in water precipitates soluble albumen, while strong alcohol throws down the coagulated variety. It is not possible to detect any difference in composition between soluble and coagulated albumen, but when coagulation is determined by certain substances, as nitrate of silver, the product is a compound of albumen with the reagent used. White of egg is not a pure solution of albumen; it contains, among other things, a little alkali, which is necessary to make it readily soluble in water. Pure albumen may be prepared by adding sub-acetate of lead to the ordinary albumen solution, and so obtaining it as an insoluble compound with the salt, which may be purified by washing. The lead is removed by means of carbonic acid, followed by sulphuretted hydrogen. Albumen, when dry, forms a pale yellowish mass which is easily powdered; it swells up in water like gelatine, but dissolves with difficulty unless a little alkali is added. Dry albumen may be heated to 100° C. without coagulation. Coagulated albumen dries to a translucent, brittle yellow mass, which will absorb about five times its weight of water.

Asphalte, or mineral pitch, is also called Jew's pitch, or bitumen of Judea, because it is found upon the shores of the Dead Sea. It is, in general, soluble in fats and oils (Nièpce is stated to have used oil of lavender and benzene in his experiments), and also in solutions of alkalies and alkaline carbonates. By extracting asphalte successively with alcohol, ether, and chloroform, the parts dissolved vary considerably. The first is yellow, oily, strong-smelling, and very little, if at all, sensitive to light; the second is brownish black, brittle, nearly odourless, and

sensitive ; and the chloroform extract yields a residue that is black, brittle, odourless, most sensitive to light, and contains more sulphur than the others.

Cellulose ($C_6H_{10}O_5$) constitutes the framework of plants. Elder pith, cotton, linen, hemp, unsized white paper, are very nearly pure cellulose, and may be further purified by successive and repeated treatment with dilute alkalis, dilute acids, alcohol, ether, &c., for cellulose is not affected by any of the more usual solvents. Cellulose is remarkably stable when pure, but readily decays when in contact with other decomposable substances, as is seen in rotting vegetable matter. Strong sulphuric acid dissolves cellulose and changes it into a sugar. But if the strong acid is mixed with half to a quarter of its bulk of water, a few seconds' immersion in it of unsized paper, followed by washing in weak ammonia, gives what is called parchment paper. It is stated that a finished silver print may be treated in this way without injury to the tone, and that in the parchmentising a slight contraction of the paper takes place which proportionately increases the sharpness of the print. Unsized paper plunged into strong nitric acid and then washed is so toughened that it may be rubbed between the hands under water without injury. Cellulose is soluble in a solution of oxide of copper in ammonia, and by a very partial action of this reagent upon paper, enough of the paper is attacked to form a varnish that makes the sheet waterproof. This is the principle of the manufacture of Willesden paper. Strong nitric acid, especially when mixed with sulphuric acid, gives the nitrates of cellulose, but in the preparation of these compounds the sulphuric acid, doubtless, acts in other ways than merely as an aid to the nitric acid. When the action of the acids is prolonged, a tri-nitrate is produced, ($C_6H_7(NO_2)_3O_5$) which is the principal constituent of the explosive gun cotton used in warfare ; but when the acids are slightly diluted and allowed to act for a few minutes only, the di-nitrate ($C_6H_8(NO_2)_2O_5$) appears to be the principal product. This last preparation is called pyroxylin. It is soluble in certain ethereal liquids, and a solution of it in a mixture of alcohol and ether constitutes collodion.

Even strong hydrochloric acid does not affect cellulose, but chlorine, in the presence of water, destroys it: hence the bleaching of paper, or the materials from which it is to be manufactured, demands great care, and it is necessary to neutralise the chlorine that remains with an "antichlor." The commonest antichlor is hyposulphite of sodium, because it is the cheapest and most efficient of the available compounds, but its use should be avoided in making paper for photographic purposes.

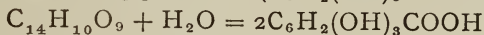
Concerning alcohol (C_2H_5OH) it is only necessary to explain a few common terms. "Absolute" alcohol contains not more than one or two per cent. of water. "Proof spirit" contains approximately half its weight of water. "Methylated spirit" contains at least four or five per cent. of water, and ten per cent. of crude wood spirit added to make the alcohol nasty enough to be practically useless for the preparation of beverages. Methylated spirit is free from duty, and it is illegal to purify it, but it is sufficiently good for general purposes, sometimes even for the preparation of sensitive silver compounds. In buying methylated spirits it should be seen that there is no gum in it, that it is not "methylated finish," or it will become turbid when mixed with water, and varnish any surface upon which it evaporates.

Ether [$(C_2H_5)_2O$] is exceedingly volatile, and its vapour is heavy and easily inflammable. It is dangerous to use ether, or liquids that contain it, in an apartment that has a naked flame in it without great care, and in small dark-rooms, tents, etc., a bottle containing ether should never be opened. What is called "methylated ether" has been prepared from methylated spirits, and may be good enough for photographic purposes.

Acetic acid ($C_2H_4O_2$) is prepared by the oxidation of alcohol, as in the manufacture of vinegar from fermented liquors, or by heating wood in closed retorts, when the watery part of the distillate contains this acid in considerable quantity. The acetic acid used in the arts is made by the latter method, and in its crude state it is called pyroligneous acid. Pure acetic acid is solid at temperatures below $15^{\circ} C.$ (or about $60^{\circ} F.$), and commercial samples

are generally described as being "glacial" or solid at a certain temperature. The higher this temperature the stronger is the acid. An acid that contains twenty-one per cent. of water has a higher specific gravity than either a stronger or weaker sample. The specific gravity is not, therefore, a certain guide to the amount of water present. Strong acetic acid is highly corrosive, and will blister the skin if allowed to remain on it.

Tannic, gallic, and pyrogallic acids are simply related to one another. The active constituent of tanning materials (gall-nut, &c.) appears to be digallic acid ($C_{14}H_{10}O_9$) combined with glucose. By boiling it with dilute acids the glucose is separated, and the digallic acid takes up water, becoming gallic acid ($C_6H_2(OH)_3COOH$), thus—



When gallic acid is heated it volatilises, and the crystalline substance that condenses, which Scheele considered to be unchanged gallic acid, is what we know as pyrogallic acid ($C_6H_3(OH)_3$). By the heating the gallic acid loses carbonic anhydride, thus—



It is not necessary to prepare gallic acid first, as the dried aqueous extract of gall-nuts gives pyrogallic acid when it is heated. If gallic acid is dissolved in glycerine, and the solution is heated to a temperature of 185° to 200° C., pyrogallic acid is produced, with effervescence due to the escape of carbonic anhydride, and if glycerine is desired in the developer, this method may be useful on account of its cheapness. Pyrogallic acid does not possess those characteristic properties that chemists understand as invariably associated with acids, and hence it is sometimes called "pyrogallol." Pyrogallic acid is a more powerful reducer or developer than gallic acid; it reduces silver nitrate in solution immediately unless its action is retarded, as by the addition of acetic acid. It easily dissolves in two and a half times its weight of water, and the solution gets brown by absorbing oxygen from the air. In the presence of an alkali the darkening is more rapid. Tannic, gallic and pyrogallic acids give black colours with ferric salts.

Hydroquinone [$C_6H_4(OH)_2$], also called quinol, is a white substance that dissolves easily in water. It may be purified by sublimation, or by crystallisation from a solution of sodium sulphite. When silver nitrate is added to its aqueous solution it slowly precipitates metallic silver, and in this reaction it shows its characteristic difference from pyrogalllic acid and eikonogen, both of which very rapidly precipitate silver under the same conditions.

Eikonogen [$C_{10}H_5(OH)(NH_2)(NaSO_3), 2H_2O$] is the sodium salt of amido- β naphthol-sulphonic acid. It was first described by R. Meldola in 1881, and in 1889 M. Andresen, of Berlin, introduced it as a developer. It can be recrystallised from a solution of sodium sulphite.

CHAPTER XII.

THE TRANSMISSION AND INTENSITY OF LIGHT.

WE do not know what light is. The most useful theory regards it as the undulatory movements of a something whose particles oscillate in paths approximately at right angles to the direction of propagation of the wave; but no research appears to have got at the something that moves in this way. It has been named before it is born—the “luminiferous ether.” Although the nature of light is a matter of conjecture, we know in many cases what its effects are, and how to control those effects. We know that light travels from a luminous object, and the rate of its movement can be experimentally demonstrated, though the time occupied in passing over terrestrial distances is so small as to be inappreciable except by means of specially-made apparatus.

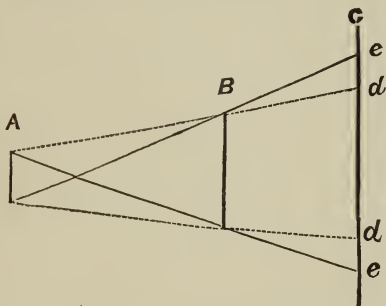


FIG. 1.—A, luminous surface; B, opaque object; C, screen upon which the shadow is cast.

Light travels through homogeneous media in straight lines, and, therefore, any opaque substance introduced into the path of light that emanates from a point produces a sharply-defined shadow. But it is practically impossible to

get a luminous geometric point; and as all sources of illumination (except an individual star) have a sensible magnitude, they cannot give a sharp shadow. In fig. 1, d, d mark the limits of the true shadow, but the full light falls upon the screen only beyond e, e . The two spaces from d to e show a perfect gradation from darkness to full light, and are technically called the "penumbra." The extent and richness of gradation of the half-lights in photographic pictures is entirely controlled by the size and position of the surface that illuminates the object photographed, or, when more than one illuminant is employed, their relative sizes, positions, and intensities.

If a point of light shines through a hole upon a screen, the patch of screen that is illuminated will be of the same shape as the hole, but larger. The continuous lines in figure 2 illustrate this. If the distance of the light from

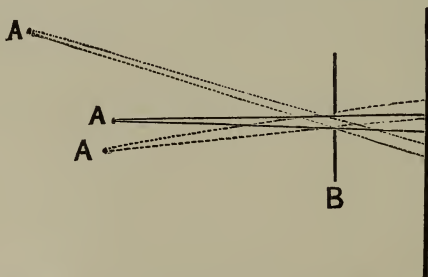


FIG. 2.—A, A, A, shining points; B, perforated screen.

the hole is many times the distance of the hole from the screen, the increase in size will be inappreciable, and may be practically neglected. Any number of shining points will act in the same way, and each quite independently of any other, as shown by the broken and dotted lines in fig. 2. Now, as everything whatever that can be photographed may be regarded as an infinite number of luminous points, some groups of points shining very feebly, and others more strongly, according to the brightness of the different parts of the subject, it is possible to get an image with a simple hole and a screen. As the hole must be small, it is technically called a "pinhole," and as pinhole

photography has such great advantages, we might be tempted to think that if sufficiently sensitive plates were available, the use of lenses, with the numerous troubles they introduce, would be very much restricted; but a complete survey of the question reveals the error of such a notion. Though the pinhole gives an absolute "depth of definition," and no distortion, except that due to the projection of the image on a flat plate, it is impossible for it to give sharp definition.

To represent what ought to be a mathematical point by a round patch one-hundredth of an inch in diameter is generally considered as the minimum of sharpness in definition that is permissible in the more usual sizes of photographs. Now, a pinhole of this character would scarcely give a workable amount of light even for bright subjects. The sharpness of definition is inversely proportional to the diameter of the hole, while the intensity of illumination is proportional to its area, or the square of its diameter; so that, for example, to double the sharpness of definition, the diameter of the hole must be halved, and by so doing the intensity of the illumination is reduced to one-quarter. But as the hole is made smaller the phenomena of diffraction become more marked, that is, the bending of light round the edge of the hole, or, more strictly, the behaviour of the light as it passes through the hole, as if the hole itself were a source of light. This is obviously directly antagonistic to sharpness of definition. Captain Abney states (see *Photography*, II., 387) that the diameter of pinhole that will give the sharpest definition may be found by multiplying $\cdot 008$ of an inch by the square root of the distance in inches of the hole from the plate. A pinhole of double the diameter indicated will give results very little inferior, and effect a great saving in the time of exposure.

The intensity of illumination in general, besides being proportional to the area of the opening through which the light is admitted, is also dependent upon the angle that the pencil of rays makes with the illuminated surface. In figure 3 the horizontal lines stand for a pencil of rays, and it is obvious that the screen indicated by the perpendicular

line receives this pencil upon a smaller surface than an oblique screen placed in the direction of the dotted line. The intensity of illumination is inversely proportional to the extent of surface over which the light is spread; or it

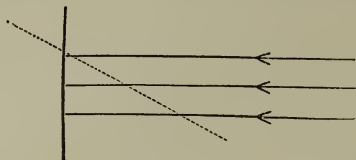


FIG. 3.

diminishes with the obliquity of the pencil in proportion with the cosine of the angle which the incident ray makes with the normal to the surface. This principle comes into action when the swing back of a camera is used, though so slightly as to be practically negligible. It is in photographic printing where much time may be lost through not placing the frames "square" to the source of light; and the loss in this case is aggravated by the reflection from the glass, which rapidly increases with the obliquity of the incident pencil.

It is not possible to estimate the intensity of light, because there is no practical zero or unit; but there are many methods that serve to compare light intensities together. Photometry, however, is not of primary importance to the photographer, because he has not so much to do with the visibility as with the chemical influence of light.

Many actinometers have been devised to measure the chemical power of light, and though each is, perhaps, useful, no one is of universal applicability, for obviously each measures only those kinds of light that affect it. The staining power of light upon chloride of silver is not equivalent to its decomposing action upon a mixture of dichromate of potassium and gelatine, and though the first is successfully used every day as a measure of the second in carbon printing, it is not an accurate indicator. A piece of ordinary silver paper may require twice as long exposure on one day as another before a standard tint is brought

out, but it does not therefore follow that a gelatino-bromide plate must have twice the exposure to give an equally developable image. But such an indicator, although it is not exact, is a very much better guide than the unaided eye, and the convenient forms of actinometers now to be obtained deserve a far more extended use than they enjoy. The chemical effects of different sorts of light, and the effects of various aerial and other absorbents, are subsequently referred to in more detail.

Actinometers have been constructed in which the chemical effect has been allowed to proceed for a unit of time, and the result has been measured, or the change has been allowed to reach a uniform result, and the time has been observed. Bunsen and Roscoe used a mixture of hydrogen and chlorine, and estimated the amount of hydrochloric acid formed. H. Draper used ferric oxalate, and noted the amount of carbonic anhydride given off by its decomposition; but paper prepared with a silver salt is generally the most convenient for practical purposes.

Sensitometers are instruments for comparing the sensitiveness of sensitive surfaces, and require a light that shall be uniform from time to time, and reproducible at any place as may be desired. Such a standard light has not yet been shown to be possible, nor is there any known means of discovering the difference between what might be an accepted standard and an actual light made to be as near to it as circumstances allow. There are so many matters that influence actinism that it is highly probable that uniformity will never be attained. Warnerke's sensitometer is the instrument often used in practice in testing developable sensitive surfaces, and the light used is a screen coated with luminous paint, and excited just before the test is made by burning a piece of magnesium ribbon in front of it. A screen with a series of tints of graduated depths is placed over the plate to be tested, and produces a graduated series from the uniform light. A more perfect method of graduating the light that reaches different parts of the plate from a uniform source is to employ a series of varying areas of a uniformly illuminated surface. An apparatus embodying

this principle was made by Arthur Taylor in 1869. He had a box containing a series of short wide tubes, each of which was open below to the sensitive surface, and closed at the upper end with a diaphragm perforated with a certain number of exactly uniform holes. The intensity of the light acting upon the sensitive surface at the bottom of any tube is proportional to the number of holes in the cover at the upper end of the tube. More recently Messrs. Mucklow and Spurge have made a similar instrument, but the diaphragms have one opening each, the openings being made of the required sizes. It is obvious that when a developable film is being tested, the light must be graduated, because a uniform effect cannot be secured (when the time would be in inverse ratio to the sensitiveness), as the result is not apparent until development.

CHAPTER XIII.

REFLECTION BY PLANE AND CONCAVE MIRRORS.

WHEN light impinges upon a surface of any sort, a part of it is invariably reflected. Most ordinary objects scatter the light in all directions, but polished surfaces reflect regularly, that is, they simply change the direction of the pencils of light that impinge upon them, the incident and the reflected rays always making equal angles with the reflecting surface.

Any surface that is used to get regular reflection is technically called a "mirror," and according to the shape of the mirror, whether flat or curved, so it is termed plane, convex, concave, cylindrical, parabolic, &c.

The commonest example of the plane mirror is the ordinary looking-glass. The plane mirror does not produce any true image, but as it bends the pencils of light in almost any direction, it enables one to see round a corner.

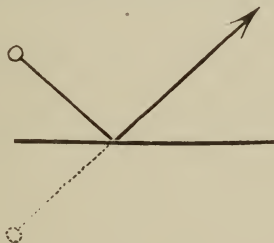


FIG. 4.

The effect of a plane mirror is shown in fig. 4. The eye sees the ball, and also a reflection of it, because the light that emanates from the ball in the direction of the line towards the mirror has its direction changed, and enters the eye. If light from the same object reaches the eye in

two distinct directions, the effect is the same as if there were two objects, for two images are produced upon the retina, and the eye knows nothing whatever of anything outside itself, but only interprets the light that enters into it. A reflection of this sort that appears like an image, though it is not one, is called in optical language a "virtual" image.

The effect of looking at an object by means of a plane mirror instead of directly, as when we use a looking-glass to view ourselves, is to cause a lateral inversion in the appearance of the object; the right-hand side becomes the left, and the left becomes the right. The same effect is produced by viewing a print or transparency through from its back. All photographs produced direct in the camera (Daguerreotypes, collodion positives, &c.) are laterally inverted, and so also are single transfer carbon prints. Ordinary negatives are inverted laterally, but as a second lateral inversion takes place in printing on surfaces where the print is not removed from its support by transference, the print is not inverted. What is technically called a "reversed negative" is a negative reversed as compared with an ordinary negative, not reversed as compared with the object photographed. In optical language, the image on an ordinary negative is laterally inverted, while that on a "reversed negative" is not inverted.

Where the process to be employed is one that naturally gives an inverted picture, the inversion can be corrected by producing a second inversion, and this is most conveniently done by photographing the reflection of the object in a plane mirror instead of the object itself, and so producing a "reversed negative." The mirror is generally placed close to the lens, as the light is more concentrated there and a smaller mirror is sufficient. The mirror used for this or any analogous purpose must have only one surface, that its effect may not be complicated by secondary reflections, and the surface used must be truly flat, or it will produce distortion of the image. It is customary to employ specially polished pieces of glass, coated with metallic silver on the front, the metal being polished. The glass is

simply a convenient support for the silver, and is not used on account of its transparency. Ordinary looking-glass is quite useless, because its reflecting surface is at the back, and an oblique ray is partly reflected from the front surface of the glass, and this gives a faint image in addition to the chief image reflected from the back of the glass. But other secondary images are produced, for the light after reflection at the coated surface is partly reflected back again from the front surface of the glass, and so passes to and fro, giving a series of images which get fainter as the amount of light reflected is reduced. In figure 5, the

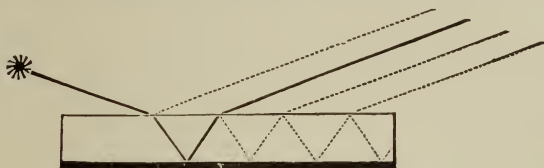


FIG. 5.

back of a looking-glass with its metallic coating is represented by the thick line, the passage of a ray is shown by the continuous line, and the broken lines indicate the reflections that produce false images. Several images so formed may easily be seen by holding a lighted candle in front of a looking-glass and looking at its reflection obliquely. The retraction or bending of the pencil of light, as it enters the glass, is discussed in the next chapter.

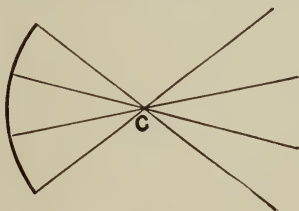


FIG. 6.

A concave mirror causes the pencils of light that impinge upon it to converge. The law that the angles of incidence and reflection are equal applies to all reflecting

surfaces, and it is therefore not difficult to trace upon paper the effect of any mirror upon the direction of any ray of light. In the figures 6, 7, and 8 the arcs that stand

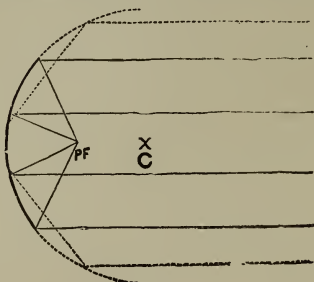


FIG. 7.

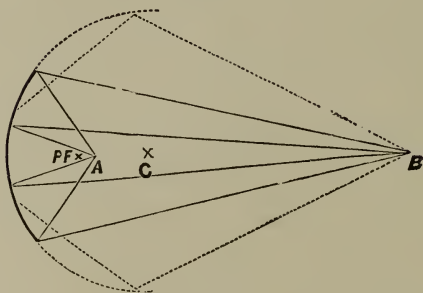


FIG. 8.

for curved mirrors are struck from the points marked C, and this point is called in each case the centre of curvature of the mirror.

If a luminous point is placed at the centre of curvature of the mirror, the rays emanating from the point travel in the direction of radii of the sphere of which the mirror is a part, and those rays that impinge upon the mirror are reflected back along their original paths to the luminous point, and add their effect to the light emanating in the opposite direction, as shown in figure 6. This is the part that should be played by the reflector in optical lanterns, enlarging apparatus, &c. The size of the mirror should be

such that when the condenser, the light, and the mirror are properly placed, the diverging bundle of reflected rays fully covers the condenser. For such purposes the spherical concave mirror is what is theoretically required.

If the luminous point is moved to the position half-way between the centre of curvature and the surface of the mirror, the reflected light forms a bundle of approximately parallel rays, as shown in figure 7, excluding the dotted lines; and, conversely, if parallel rays impinge upon such a mirror, they are brought to a point or focus half-way between the centre of curvature and the mirror, and this point accordingly is called the "principal focus." It is a mistake to suppose that by putting a luminous point in the principal focus of a concave mirror we have *only* parallel rays opposite the mirror; the parallel rays produced by the mirror mix with the divergent rays emanating directly from the luminous point itself, and at a certain distance from the mirror, which may easily be demonstrated geometrically, the parallel and divergent rays are sensibly equal in intensity. Nearer the mirror than this the bundle of divergent rays is more intense, and further away it is less intense, than the bundle of parallel rays. If light from so distant a source, that the rays are practically parallel impinges upon a concave mirror, it is concentrated at the principal focus of the mirror, as shown in figure 7, but this concentration is only approximate, though it is drawn as if it were exact so far as the unbroken lines go. The dotted lines of the figure show that if the curve of the mirror is continued, the concentration at the principal focus is not even approximate. This lack of focussing power is called "spherical aberration," and it is always present in spherical mirrors, though in a mirror of small angle* it may, under certain circumstances, be practically neglected.

In figure 8, it is obvious that a point of light, such as B, that is further from the mirror than its centre of curvature, has its light that impinges upon the mirror brought to an approximate focus at a point between the principal focus and the centre of curvature, at A. Conversely, a luminous

* That is, a mirror that forms only a small portion of the sphere of which it is a part.

point at A would have its light concentrated at B, and these two points, or any pair of points similarly related to one another, are therefore called "conjugate foci." Spherical aberration in this case is also shown by the dotted lines.

If one luminous point is reproduced, so to speak, by having a part of its light brought to a point in a different place, it generally follows that other luminous points will be correspondingly reproduced. And as a visible object may be regarded as an infinite number of luminous points, we have here all the conditions necessary to obtain a true image—true in the sense that it may be received upon a screen, and may, therefore, be photographically fixed upon a sensitive surface. A camera with a concave mirror instead of a lens was used by some in the early days of the Daguerreotype process, but such an apparatus is not readily amenable to modification, and allows much stray light to reach the sensitive surface. Moreover, as the sensitive surface, or a second mirror, must be between the object and the mirror, a considerable amount of light is stopped, unless the mirror is large as compared with the sensitive surface. But in stellar photography the mirror has very many advantages over the lens. It can be made larger, and, therefore, to form a more brilliant image, by a slight modification of the curve, spherical aberration can be practically eliminated, and as it is absolutely free from chromatic aberration, the whole of the chemically active light is brought to a focus exactly where the visible image is formed, an advantage that no combination of lenses can effect. As the light from stars is feeble, the stray light is not dangerously great; and as the plate used to receive the image is not large, it does not cause, either directly or indirectly, an important barrier between the mirror and the object.

Convex mirrors do not produce real images, and as they are not useful in the practice of photography, we are not called upon to discuss their properties.

CHAPTER XIV.

THE REFRACTION OF LIGHT AND THE FORMS AND PROPERTIES OF LENSES.

WHEN a ray of light passes from one medium to another of a different density, it is turned from its original path, it is "refracted," unless it impinges perpendicularly upon the surface that bounds the two media. The path of the light in the denser medium forms a smaller angle with the perpendicular to the bounding surface than does its path in the rarer medium, and for the same two media, the sines of these two angles bear a constant proportion to each other. In figure 9, a ray of light is represented by the thick line, the line A B is the

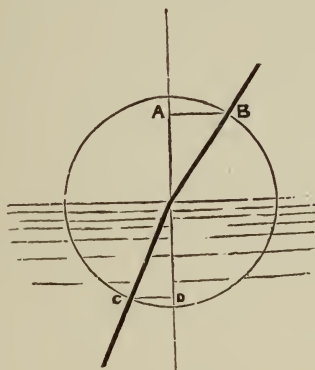


Fig. 9.

sine of the angle of incidence, and the line C D is the sine of the angle of refraction. The proportion between these lines, when the media concerned are air and water, is approximately as 4 to 3, or for air and glass, as 3 to 2. These proportions expressed as fractions are the "refrac-

tive indices," namely, $\frac{4}{3}$ or 1.33, and $\frac{3}{2}$ or 1.5. Refractive indices expressed in this manner are never more than approximate unless the light they refer to is exactly specified, because ordinary white light (or any light that is not homogeneous) is decomposed when it is refracted, the violet and blue being bent more out of the original direction than the yellow, and the yellow more than the red. The appearance which results from separating the constituents of non-homogeneous light is called a "spectrum," and in the spectrum of solar light there are certain narrow dark spaces (Fraunhofer lines) which serve as fixed points for convenient reference. Refractive indices for the D line represent as nearly as possible the effect upon the most visible part of ordinary light, and those for G or H (more nearly the latter) may be considered as correct for the average of the chemically active light that is most useful photographically.

If an object is viewed through a plate of glass (or any similar transparent medium), so that the path of the light from the object to the eye is not perpendicular to the surface of the glass, the object will appear laterally displaced, as shown in figure 10, A. It is obvious that the greater the obliquity with which the light impinges upon the surface of the glass, or the thicker the glass, the greater will be the extent of lateral displacement; hence it is possible to correct the distortion of images produced by lenses consequent upon the use of a flat surface to receive the image, by placing a flat plate of glass between the lens and the receiving surface. This distortion is an enlargement of the image in the direction of lines drawn from that point of the plate that is immediately opposite the lens.

If, however, the glass, or other such substance, has plane sides that are not parallel, the rays of light that pass through it will have their direction entirely altered, the refraction at both surfaces taking place according to the rule. The displacement of the image caused by interposing such a medium in the path of the rays is always towards the thicker part of the medium, or the base of the triangle formed by continuing the two lines that represent

the boundaries of the surfaces until they meet. It should be noted, however, that if an object is viewed *directly* through a dense medium with non-parallel sides, the *apparent* displacement of the object is towards the thinner part of the interposed substance, because we cannot but imagine that the light entering our eyes has come in a straight line.

In figure 10, B, the passage of light through a prism is

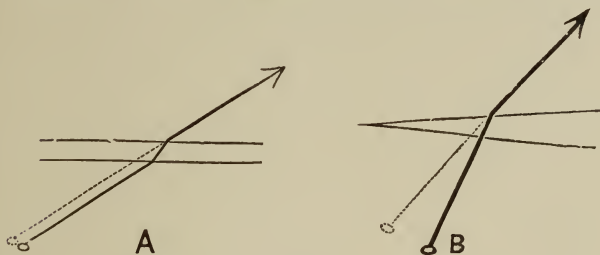


FIG. 10.

shown, and the apparent displacement of an object viewed directly is indicated by the broken lines.

If two prisms are placed base to base, light passing through them is concentrated, while if they are placed apex to apex the light is caused to diverge (figure 11). If

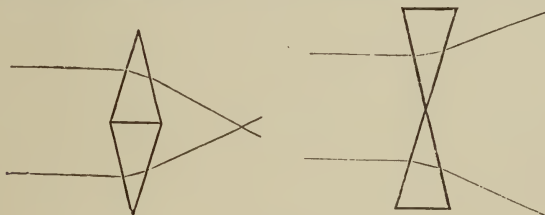


FIG. 11.

these two arrangements are made circular, so that the diagrams represent the plane obtained by cutting along any diameter, these two combinations are typical of the two sorts of lenses. The surfaces of lenses are always curved that they may be continuous, and for convenience in manu-

facture their surfaces are always spherical, although the spherical surface is not what is theoretically required.

There are three forms each of converging and diverging lenses, the former having their greatest thickness in the middle, and the latter at their edges. These six primary forms are named respectively the double convex, the plano-convex, and the convex meniscus; and the double concave, the plano-concave, and the concave meniscus, and each of them is illustrated in figure 12. The last form is some-



FIG. 12.

times called concavo-convex, but this name is needlessly confusing to the student.

Disregarding for the moment the spherical and chromatic aberrations that such lenses suffer from, we can sum up the effects that can be produced by their means in a useful and simple way. If a pencil of parallel rays of light is allowed to fall upon the surface of a converging lens the light will be concentrated to a point at a certain distance from the other side of the lens (figure 13). This

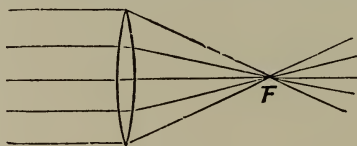


FIG. 13.

point is the "focal point," or, more correctly, "the principal focal point," and its distance from the lens is the "focal length" of the lens employed. In this, as in every other case, the refracting effect of the lens is the same whichever way the light travels through it, so that if a luminous point is brought into the principal focal point of

such a lens, the diverging rays that impinge upon its surface will be transmitted as a pencil of parallel rays. It does not at all follow from this fact that an unsymmetrical lens (plano-convex, convex meniscus) will produce the same effect with either side towards a luminous object; indeed, if such were the case, it would be contradictory to the previous statement.

If the luminous point is moved further from the lens, the transmitted rays will converge to a point (figure 14), and when the luminous object is twice as far from the

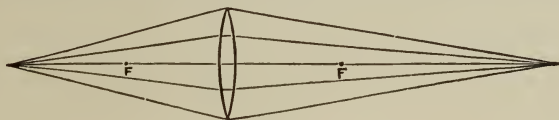


FIG. 14

lens as the principal focal point, the point of light produced on the other side of the lens, will be at exactly the same distance from the lens. Any such pair of points are called "conjugate foci." Any number of luminous points will be simultaneously reproduced by the lens, and therefore any object will give rise to a corresponding image. The comparative linear sizes of the image and its object are proportional to the distance of each from the lens.

Concave or diverging lenses cannot cause a re-concentration of light that impinges upon them, and therefore they cannot form real images. They are used for photographic purposes only to modify converging lenses.

The images produced by lenses are formed by the refraction or bending of the light; and as the various

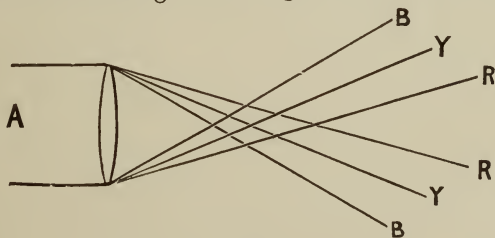


FIG. 15.

constituents of ordinary light are not equally refrangible, each constituent produces its own separate image. In figure 15 the bundle of parallel rays, A, is supposed to consist of a mixture of red, yellow, and blue lights, the three most striking colours that are found in solar light. By any given lens the blue is more affected than the yellow, and the yellow more than the red; hence, in this case, the image is not simple, but consists of three points of lights of the three colours, and in the three positions respectively as shown. If a screen is placed to receive the blue image of the point, it will be found that the blue is not pure, that it is surrounded by an orange yellow, and that this tint again is bounded by a red ring, if we assume that the brightness of the three colours is sensibly equal. The screen, in the position we are considering, receives a round patch of red light, and on this a smaller, that is more concentrated and therefore brighter round patch of yellow, and in the middle a thoroughly concentrated and therefore still more bright point of blue. The condition of affairs when the screen is removed to the focus of the red light is easily understood by the figure; the blue covers the largest space here, having spread out after being collected to a point at its focus.

This experiment at once explains why the images produced by lenses that are uncorrected for chromatic aberration are fringed with colour, for the colour in the body of the image itself is scarcely perceptible on account of the smallness of the proportion of colour taken from it to form the fringe. It is clear, moreover, that if the screen that receives the image is placed in the focus of the actinic light, the image will show a red fringe to the eye, and that a blue-tinted fringe indicates that the screen is further from the lens than the position where the brightest visual picture is formed.

This separation of light into its constituents is called dispersion, and Newton predicted that dispersion could not be neutralised without at the same time losing the effect of refraction. This, indeed, would be so if dispersion was always proportional to refraction, but, practically, a prism of flint glass that gives the same amount of dispersion as a

given prism of crown glass has a considerably less amount of refractive power. Thus it is possible by means of a flint glass concave lens to practically neutralise the chromatic aberration of a crown glass convex lens, and still to leave a residue of refracting power. This was shown to be possible by Hall, in 1733, and in 1757 Dolland constructed achromatic objectives for telescopes. Perfect achromatisation with lenses is unknown, and when a combination of two lenses is used, it is only possible to get the foci of two parts of the spectrum to exactly coincide. Hence an achromatic combination made for ocular work only, if at its best, is not suitable for exact photographic purposes. A photographic lens should be so corrected that the focus of the mean of the chemically active rays coincides with that of the brightest of the visible rays, so that the lens shall properly "work to focus." A sharper image can be obtained of the chemically active rays if the visible image is neglected, because then the available power of correcting the lens can be applied entirely to the actinic rays; and lenses have been so constructed for photo-astronomical work. With such instruments, however, focussing cannot be done in the ordinary way, the position of the actinic image must be determined, and the sensitive plate carrier must be fixed once for all in its proper place.

If a double convex lens with no diaphragm is attached to a camera, it will be found impossible to get as sharp definition as is generally desired in a photograph; but if, by means of suitably cut pieces of blackened card placed close to the lens, the light is allowed to pass only through its central part or its outer part, it will be found possible to focus the picture, and it will be observed that the picture produced by the centre of the lens is markedly further from the lens than the picture produced by its outer part. This is because the surfaces of the lens are spherical; and the want of coincidence of the focal points of different parts of the lens in passing from its centre to its circumference is, therefore, called "spherical aberration."

A plano-convex lens, with its convex side towards the distant object—or, better still a double convex lens, the radii of the curved surfaces of which bear the proportion

to each other of about one to six—suffers very little from spherical aberration. Such a lens so arranged is occasionally useful as a finder, because its aperture may be large, and the image it gives proportionally bright; but the field over which it gives a good enough definition for practical photography is too small to be useful. By turning such a lens round with its most convex side towards the focussing screen, a larger field is covered; but the definition throughout is confused. The spherical aberration consequent on the position of the lens may be reduced by the use of a diaphragm. The ordinary single landscape lens of modern make is almost invariably of the meniscus form, because the field covered is still larger than with a plano-convex; but the spherical aberration is greater with the meniscus, and it is therefore necessary to use a smaller stop.

Spherical aberration can be corrected in combinations of lenses by the use of suitable curves, and lenses that are corrected so that they can be used with their full aperture are said to be “aplanatic,” though this term is often employed in a very vague, if not an incorrect, sense.

CHAPTER XV.

THE SPECTROSCOPE, COLOUR SENSITIVENESS, AND THE ABSORPTION OF LIGHT.

WE have already seen that when light passes through a dense medium such as glass, whose opposite sides are not parallel, the path of the light is bent out of its original course; and also that whenever refraction is produced by a single medium the constituents of the light are unequally refracted, and therefore separated. A prism, as optically understood, is a piece of glass, or its equivalent, with its opposite sides parallel in one direction and inclined in the other direction; and a spectroscope in its simplest form is a prism and a screen with a narrow slit in it for the light to pass through before it impinges upon the prism, so that the separated constituents of the light may overlap to the least possible extent. By means of such an instrument, any light will give its own characteristic spectrum, and so reveal its exact nature to the scientific observer.

If a non-luminous flame is made yellow by common salt, and this yellow light is examined by a small spectroscope, a yellow image of the slit is seen, and if then some potassium nitrate is introduced into the flame, there will be added a red image of the slit on one side, and a violet image, at a considerable distance, on the other side of the yellow one. The potassium compound gives out a mixture of red and violet light, and as the red is refracted less than the yellow, and the violet is refracted to a greater degree, the three sorts of light are separated, and are each as clearly visible as if none other was present. If we find in using the same instrument that another luminous body gives a yellow or red image of the slit, or gives a yellow or red light at the same place as the sodium or potassium compound, then we know that we have the same sort of

light; for light from any source whatever, if equally refrangible, is similar in all its other known properties.

If a gas or candle flame is examined with a spectroscope, a band of colours similar to the rainbow is seen, and here there is no interval, all sorts of visible light are emitted by the flame, and the innumerable images of the slit overlap each other all the way. With the finest slit and most perfect instrument no gaps can be found, hence the light emitted is said to be of all degrees of refrangibility, and the spectrum produced is continuous. The spectrum of solar light is practically continuous though hundreds of gaps of darkness occur, because these gaps are very narrow, and most of them immeasurably so. From the nature of the slit used, these spaces appear like lines, and they are called the Fraunhofer lines, after the philosopher who first elaborately mapped them. These lines are made use of to indicate a definite part of the spectrum, or, in other words, a certain sort of pure or unmixed light. The lines A B C are in the red light, D is in the yellow, E in the green, F in the blue, G in the violet, and H in the extreme violet.

If a continuous spectrum or the spectrum of solar light is allowed to fall upon a sensitive surface, the result will clearly show what sort of light most affects the sensitive material used. It will be found in all ordinary cases that the photographic effect is at its maximum at about the limit of visibility in the violet, and that it extends on both sides of this centre, getting smaller with more or less regularity. Thus, a large portion of the light that is photographically useful is invisible to us, and therefore it is, and always will be, impossible to estimate photographic exposures by one's eye alone with any exactness. An actinometer measures photographic activity by a photographic effect, and is therefore very much more reliable than the mere visibility of light, though, indeed, even it is not exact, because the proportional effects of different parts of the spectrum are not uniform when acting upon different sensitive substances, or upon the same sensitive substance under different conditions (printing out, developing, &c.)

Iodide of silver with ordinary development is sensitive

to the ultra-violet and the violet ; chloride of silver with development is affected chiefly by the ultra-violet, also by the violet, slightly by the blue, and very little by the green ; while bromide of silver is chiefly affected by the violet and blue, very considerably by the ultra-violet, to a smaller extent by the green and yellow, and even slightly by the red, if the exposure is prolonged. As silver bromide is sensitive over a wider range of colour than either of the other salts, it is the most suitable for the production of ortho-chromatic plates.

By means of spectrum analysis one can not only determine the nature of any given light, but also the absorbing effect of any medium that is only partially transparent, or transparent to only certain kinds of light. The most important use of absorbing media is in the construction of dark-room windows, and lanterns that are required to give the safest light for the manipulation of sensitive materials. A crude and unscientific review of the facts of the case led to the general use of ruby glass when rapid gelatine dry plates were introduced. But ruby glass is a very faulty material for this purpose, because an insufficient depth of tint allows a little blue light to pass through it, an amount that is useless as contributing to the visible illumination, but highly dangerous to sensitive surfaces because of its great photographic activity. If the ruby tint is deepened to get rid of this element of danger, it is at the expense of so much safe light that the remaining illumination is no more than sufficient to make the darkness visible. No light is absolutely safe—that is, any visible light will affect a gelatine dry plate if time enough is allowed. It remains, therefore, merely to find that light which for a given amount of photographic activity yields the greatest illuminating effect. It is almost universally acknowledged now that yellow is superior to red so far as ordinary sensitive materials are concerned, but it is necessary to beware lest the yellow medium is such as will allow too much green light to pass through it.

Other absorption effects sometimes demand considerable attention. In photographing interiors where the windows are glazed chiefly with yellow and red glass, a

protracted exposure will be necessary, although the flood of light appears such as to warrant a short exposure.

The moisture in the air is a great enemy to rapidity of exposure, and its effect is not only uncertain, but chiefly invisible, and therefore not to be estimated by the most experienced eye. In general language, about half the photographically useful light that reaches us from the sun on the best of days consists of ultra-violet radiations, and is therefore quite unable to affect the eye; and of the other half, the violet and blue, which are the most useful, have a very small visible illuminating effect. The air may therefore be photographically foggy when it is quite clear to the eye, and the visibility of a fog is always very much less than its photographic effect. However clear the air may be it absorbs useful light, and therefore exposures must be shortened at high elevations, because there is less of the air intervening between the sun and the object; and the nearer the sun is to the horizon, whether at early morning or late in the day, or in the winter, or in regions remote from the equator, the more must the exposure be lengthened, because the oblique rays have a greater distance of air to travel through.

The proportional chemical activity of the light at Iceland, Manchester and Cairo, on the 25th March, for each hour during the day, is shown in the following table:—

A.M.	P.M.	Iceland.	Manchester.	Cairo.
6 ..	6 ..	0' ..	0' ..	0'
7 ..	5 ..	02 ..	22 ..	1'74
8 ..	4 ..	1'53 ..	5'85 ..	20'12
9 ..	3 ..	6'62 ..	18'71 ..	50'01
10 ..	2 ..	13'27 ..	32'91 ..	78'61
11 ..	1 ..	18'60 ..	43'34 ..	98'33
Noon	..	20'60 ..	47'15 ..	105'30

In this connection it is interesting to notice the chemical activity of the light that reaches the various planets:—

Neptune ..	04	Mars ..	137'1
Uranus ..	10	Earth ..	318'3
Saturn ..	35	Venus ..	608'9
Jupiter ..	11'8	Mercury ..	2125'0

Presuming other things to be equal, photographic exposures on the planet Mercury would only be about seven times as rapid as with us, while the equivalent of

an exposure of one second with us is about a minute and a half at Saturn, five minutes at Uranus, and two hours at Neptune.

The two tables just given are due to Professor Roscoe.

Many terrestrial substances exercise a very important absorptive effect upon the ultra-violet rays, and are therefore detrimental to photographic work when the available light has to pass through them. Dr. W. A. Miller made an extensive series of experiments in this direction, and he found that while rock crystal was the most transparent to the ultra-violet rays, ice, water, white fluor-spar, and pure rock salt, in thicknesses up to $\cdot 75$ of an inch, were scarcely at all inferior to it. By passing the light examined through a space two feet long filled with either air, hydrogen, carbonic acid, carbonic oxide, or ammonia, there was no appreciable loss. But among a large number of other bodies examined, solids, dissolved substances, liquids, and gases, there is not one that does not stop a considerable proportion of photographically active light. The solar light, however, that reaches us is considerably reduced by passing through our atmosphere, and the majority of substances tested do not appreciably affect the solar light available under ordinary circumstances. Those given in the following table are the only ones likely to interest the photographer.

The last column indicates the extent of the ultra-violet transmitted, the ultra-violet of the solar spectrum being divided into ten degrees. The higher the figure, therefore, the less the absorption observed; but these figures cannot in any way be made to show the proportional diminution of photographic action, because the ultra-violet of the solar spectrum is not of uniform intensity throughout its extent.

Material tested.	Thickness of layer.	Ultra-violet transmitted.	
<i>Solids.</i>	<i>In inches.</i>	<i>In solar spectrum.</i>	
Crown glass (greenish)	·74	..	6·5
Flint glass	·68	..	5·5
Faraday's optical glass (pale yellow) ..	·54	..	1·5
<i>Saturated solutions of solids.</i>			
Hyposulphite of soda	·75	..	8·5
Silicate of soda ..	"	..	"
Nitrate of silver ..	"	..	6·0
Cyanide of potassium (not quite pure) ..	"	..	5·5
Ferrous sulphate ..	"	..	5·0
<i>Liquids.</i>			
Nitric acid, S.G. 1·3 (colourless)	"	..	6·5
Oil of turpentine ..	"	..	4·5
Bisulphide of carbon ..	"	..	2·5
<i>Vapour of</i>			
Bisulphide of carbon ..	24·0	..	1·5

The use of glass lenses, therefore, tends to uniformity of exposure under various conditions of the atmosphere, for their retarding effect only comes into play when the air is free enough from mist to transmit those extreme ultra-violet rays that glass absorbs.

PART II.

APPARATUS.

CHAPTER I.

CAMERAS.

THE camera is an apparatus to support the lens and the sensitive plate, and to exclude all light from the plate except what passes through the lens. The quality and pattern of the instrument have no direct influence whatever upon the picture, but with a convenient camera the operator can adjust the position of his plate and lens with more rapidity, and perhaps with more certainty, than if he had only a makeshift apparatus. The various changes possible with any camera are, therefore, to be valued as conveniences, and when it is stated that any elaboration is indispensable, it simply means that without it the operator would be constantly hampered, and would be often losing time by having to devise means for gaining the desired end.

Camera bodies are most often made of the bellows form, and this has not only the advantage of portability and ease of focussing, but the light transmitted by the lens that impinges upon the walls of the camera is reflected forwards or across the camera rather than on to the sensitive plate. Sliding-body cameras, whether of the old form, or with more than one draw, as in Stanley's telescopic camera ; and solid body cameras, whether they fold like the old-fashioned instruments, or are rigid as in some patterns of hand cameras, allow the light that impinges upon their flat sides to glance off on to the sensi-

tive plate, especially at its edges. This should be guarded against by diaphragms fixed at regular intervals within the camera, with rectangular openings large enough to allow light from every part of the lens to reach every part of the sensitive surface. A less efficacious method is to line the chamber with black velvet, and so reduce the reflection from the sides as far as possible, instead of doing away with it altogether.

That part of the camera that carries the lens is always spoken of as the camera front. It is often necessary to raise the lens to get the upper part of a high building on to the plate, or to reduce the extent of foreground; and occasionally it is required to lower the lens when the photographer is obliged to occupy a high position. The camera front, therefore, ought always to slide upwards—say two inches or more for a whole-plate camera—and it is well if it will slide downwards about an inch for this size. A horizontal movement of the lens is very rarely desirable, unless only a part of the sensitive surface is to be exposed and the lens is wanted opposite that part; but if the camera is constructed so that it must be turned on its side for pictures taken with the longest direction of the plate vertical, then what is usually in landscape work the horizontal movement of the front becomes a vertical movement, and is a necessity.

Any movement of the lens that places its axis at other than a right angle with the focussing screen is to be guarded against. The notion that a swinging front is in any way a substitute for a swinging back is erroneous. However the back swings, the lens, in its normal position, points to the centre of the sensitive surface; but the front cannot be swung in any direction without upsetting this condition. A front that swings vertically is, however, useful in conjunction with the vertical swing of the back if the front and back are kept parallel, as the effect produced is that of an abnormal amount of rise or fall of the front; this is especially to be commended where the front is small, and the principle is well shown in McKellen's camera and its many imitations.

To do good work under ordinary varying circumstances,

the back frame of the camera must swing vertically (that is, like a toilet-table looking-glass), even with the smallest of cameras. This is admitted by probably every maker; but the equal importance of having some means of knowing when the back frame is vertical is not recognised as it ought to be. It is true that anyone can carry a spirit-level, but this is a lame and troublesome substitute for a level fixed to the camera itself. It is important to notice that the level is for the purpose of indicating when the sensitive surface is vertical, and it is therefore preferable to fix it to the back frame of the camera; and a round level is more convenient and compact than two straight levels at right angles to each other. The vertical swing is used to keep the sensitive plate vertical when the camera is tipped in taking architectural subjects, that the vertical lines, as produced in the picture, may not converge. This movement of the plate throws the top and bottom of the picture out of focus, for the nearer the object is, the further off is the image from the lens, and the movement of the plate necessary to keep the vertical lines true brings the upper part of the sensitive surface near the lens, and it is this part that receives the image of the nearer part of the object. Thus definition is sacrificed for correctness of form, and to restore the lost sharpness a small stop must be used.

If the swing-back is used in the other direction—that is, drawing the top part of the plate away from the lens—focussing is made easier, because the near foreground is delineated on the surface further from the lens; but this use of the swing-back always distorts the picture, producing a perpendicular convergence that includes an undue proportion of the upper part of the subject. This aid to focussing is occasionally useful in skilled hands, but is never necessary except when large plates are employed.

The horizontal swing is exactly comparable to the vertical swing used in the manner last described, and accordingly introduces distortion for the sake of ease in getting definition without having recourse to so small a stop in the lens as would otherwise be necessary. It is used in focussing a row of houses, trees, etc., that recede from the

camera, but it has the very undesirable effect of dwarfing the distance, and so giving a somewhat similar result to what would be obtained by using a lens of shorter focal length at a point of view nearer the subject photographed.

Better advice cannot be given to the outdoor worker than to keep his plate perpendicular and the lens axis at right angles to the plate, and to use the possibilities of deviating from these rules to the very least extent. When he is tempted to take advantage of the facilities for focussing just mentioned he should bear in mind that he thereby distorts the representation of the view before him, and exaggerates those undesirable features already so obvious, especially in small photographs, that make the picture deceptive. Although the picture is included within a parallelogram, the amount of subject represented as seen by the eye is bounded by lines which are parallel in one direction, but incline towards each other in the other direction. It should be noticed that in those cameras that have to be turned on the side for a vertical picture the horizontal swing becomes a vertical swing in this case, and is therefore necessary.

It is well to have the swinging centres so fixed that their axes cross at the centre of the plate; but it is often worth while surrendering this point for the sake of the portability that can be obtained by adjusting the back frame of the camera on the hinges at its lower part that also serve for closing the apparatus for carriage.

The contrivance for holding the sensitive material, technically called the "back," has been modified in a great number of ways, but the well-known book form of double-back continues to be the most popular, in spite of its defects and its competitors. Its two chief drawbacks are its great cost and the fact that it slides into position. The evil of the sliding is not so much that the camera may be moved as the back is being adjusted, but that the surface it slides against is rarely so close fitting to the face of the double back that it can be depended upon to exclude light. In the cameras of the Sciopticon Company the back does not slide at all, but is pushed into a recess; this device perfectly obviates the trouble, but it appears advisable with this

pattern to have a loose focussing screen, and this is certainly undesirable, especially for outdoor work.

Backs made of metal have some advantages over those of wood. They must, perhaps, be a little heavier, but they are more compact, and though the difficulty of excluding light where the parts move against one another is greater, it is not insurmountable. If metal backs were made by suitable special tools, so that all those of one size were the exact reproductions of each other, we should have the great advantage of cheap backs, proof against damage by exposure or wet. The Americans are far in advance of us in this matter, for they have uniform gauges, so that any maker's back will fit and be in register in any maker's camera of the same size. With our present system of every maker for himself it seems hopeless to imagine that the first cost of making the necessary tools for constructing uniform backs in metal of the various sizes would prove a profitable undertaking, as there would be a very limited number of cameras that such slides would fit.

The weakest parts of camera backs themselves, so far as concerns the exclusion of light, are the openings where the slides are drawn out. This difficulty is greatly increased when the slides neither fold back nor draw right out. It will scarcely be thought possible by those who do not know it as a fact, that there was in 1887 a new pattern of double-back on the market, the slides of which stood out straight and held the focussing cloth off, as if purposely to give daylight free access to the sensitive surface through the opening between the slide and the back that was wide enough to admit the blade of a large pocket-knife. If the back could be adjusted to the camera so that its slides were drawn downwards, the possibility of light gaining access to the sensitive plate would be very much reduced. When a double-back is opened for the removal of its plates, the plate that is at once exposed to view should always be the one indicated by the lower figure—that is, the odd number. Variety in this respect, which makers seem to think charming, means confusion and loss of time to the user.

That small part of the back frame of the camera that

receives the double-back is often detached and made square, so that it may be reversed in position for changing the plate from horizontal to vertical. To allow of this the camera must be made square, and the author considers that the added weight and bulk in half-plate or smaller cameras more than compensates for the little advantage. For whole-plate or larger cameras, however, the reversing back is an adjunct that may be regarded as a necessity.

There have been many attempts to make apparatus to carry a dozen or more plates instead of only two, but all the patterns proposed have been very justly denied an extensive patronage, except in connection with hand cameras. All such contrivances are included in the term "changing boxes," and they all suffer more or less in needing the plates for them to be more exactly cut than usual, but chiefly in not affording the plates sufficient protection from dust, and in actually stirring up what dust happens to have gained access to the box, and adding to it, by the friction of the parts whenever a fresh plate is brought to the front.

Sensitive films are most conveniently exposed in roller slides. These consist of two rollers, one that holds the film ready for use, and one that receives it after exposure, with a stretching board or its equivalent in front over which that part of the sensitive band that awaits exposure is drawn, and other minor parts that enable the operator to know when a proper quantity of the film has been wound to bring a fresh surface to the front. As early as 1854, A. Melhuish constructed a roller slide, but it was the Eastman Company in 1885 that popularised this form of apparatus. In this pattern the rollers are detachable, so that the receiving roller with its exposed film is removed bodily, and more film is introduced by slipping in a fresh roller with its charge already wound upon it.

CHAPTER II.

CAMERAS (*continued*) AND CAMERA STANDS.

FOR focussing the image it is necessary to be able to alter the distance between the lens and the sensitive surface easily, smoothly, and exactly, and yet to retain the part moved with sufficient firmness to allow of the subsequent operations. Cameras for copying and indoor work in general are preferably made with the front fixed and the back part to move, because the distance between the object photographed and the lens determines the size of the image produced, and it is very inconvenient to be unable to adjust the distance of the focussing screen from the lens without altering the distance between the lens and the object, and therefore the size of the reproduction. But in landscape work the distance of the nearest object from the lens is so considerable that an inch or so more or less makes practically no difference, and we may, therefore, focus by moving the camera front without disadvantage. This latter method also has much to recommend it, for cameras so constructed can be made lighter and more compact, which is an important consideration with the photographer who cannot employ a porter, and the back frame of the camera being fixed it cannot be jarred from its proper position by the introduction of the dark slide, &c. This last advantage is the more important, because apparatus used out of doors is more likely to work irregularly than apparatus used only in the studio, as it suffers somewhat by exposure.

Focussing is generally done by means of a screen of ground glass. Ordinary ground glass is almost useless for the purpose, because the grain is too coarse to allow the details of the picture to be seen, and the finest ground surface that can be obtained will not permit of the sharp

focussing desirable in copying subjects done in lines like engravings. For this purpose no screen will answer ; the actual image itself must be employed in focussing, and to know whether the image is produced in the proper plane, a sheet of transparent glass that has its front side marked with very fine lines is introduced in the place of the ordinary focussing screen, and a good focussing lens is adjusted so that the lines on the glass, as seen through the lens, are as sharply defined as possible. It only remains to get the image of the object before the camera at its maximum sharpness ; for if the lines on the glass and the image are simultaneously sharp as seen through the same lens, they must be in the same plane. It is stated to be preferable to have the lines on the glass in groups with intervals between the groups.

To get the advantage of this method of focussing without interfering in any way with the utility of the ordinary focussing screen, it is only necessary to cement two or three thin microscopic cover-glasses to the focussing screen by means of Canada balsam, after having drawn a few pencil lines on the spaces where the cover glasses are to be attached. It is convenient to put one in the middle of the screen and one or two at the corners. The balsam entirely obliterates the dullness of the glass due to the grinding, and leaves only the pencil marks visible.

An excellent focussing screen can be made by exposing an ordinary dry plate for a short time, and then developing it until it is uniformly and sufficiently grey, fixing, and drying. A suitable degree of opacity is thus obtained without the irregularities of necessity present when the opacity is due merely to roughness of surface. A focussing screen that shows no grain, even when magnified eighty diameters, can be prepared by inducing red fog in a gelatine plate. This is readily done by applying a ferrous citrate developer made alkaline with ammonia, and then fixing in the ordinary way. Coloured glass does not appear to be a sufficient barrier to the light to make visible the image that falls upon it, though one might imagine that glass flashed with a colour on one side would

be very similar to the glass with the coating of fogged film.

Carey Lea has recommended to varnish a glass plate exactly as is usual in varnishing a negative but to first add tartaric acid to the varnish that it may dissolve as much as possible, and to allow the excess of the acid to settle down. He states that such a film is exquisitely fine, yet not too transparent.

Temporary focussing screens may be made by covering a glass plate with a thin layer of starch, or by rubbing olive oil over a glass plate; or a wet cambric handkerchief, if it can be stretched in position, may be made serviceable.

The idea that the pictures produced by means of a camera are an indication of the value and efficiency of the instrument is very common, but quite erroneous. We have already stated that the simplest and cheapest box of deal or cardboard that will hold the lens and the sensitive plate in their right places and exclude extraneous light will give in every way as good a picture as the most expensive apparatus.

The best camera is simply the most convenient, but this is a very inclusive statement. It is not convenient to have a camera that shrinks or swells in a dry or moist atmosphere, or one that is likely to warp or crack. Hence the best workmanship, the finest wood and the most perfect polishing, are well worth what they cost. It is not convenient that a camera shall fail to draw out far enough to give a picture with any lens that it may be desired to use; nor is it convenient to find that the long-focus camera with its many possibilities, of the size required, is too heavy to be carried about.

It is impossible to suggest what pattern of instrument will be the most acceptable until it is known what work will be required of it, and what lenses are to be used. It may be taken for granted that no substantial advantage can be gained in one direction without a measure of sacrifice in another, and that all complications that are useless under the given circumstances are better absent. In the matter of portable cameras, the clumsy worker must have a simple and solid apparatus; the operator who has

porters at command or other carrying power need not take weight into consideration; but the expert operator who always carries his own apparatus is better served by a very light camera, though he certainly surrenders much that he would value for the sake of portability.

But, whatever the pattern of the instrument, it must be well made and reliable. A camera intended for honest work should be rigid in all positions. When extended partially or fully, if the back is seized by one hand and the front by the other hand, there should be no looseness evident, but a sensible oneness as if the back and front were permanently fixed with no means of adjustment. All movements must run smoothly, and this is especially to be looked to where the back or front slides on runners, a method of construction often adopted in extending baseboards or long-focus cameras. If such runners are made true they will not cause any sticking or irregularity. The front and back of the camera in their normal positions should be parallel with one another, and the axis of the lens should be exactly at right angles to the focussing screen and opposite its centre. The inside of the camera should be black all over, including the brass work, and it is well to especially look to the lens-flange and the screws that pass through the front to hold the movable fronts in place, as these parts are often left bright. The balance between strength and portability is a matter that cannot be usefully discussed without practical examples, but it may be stated that a light camera that is properly made will often be stronger than a heavier one of inferior construction.

The register of a camera—that is, the correspondence in position between the front of the focussing screen and any sensitive surface that may be introduced—should be carefully tested, especially when lenses of large aperture are to be employed. There is no method of measuring with a rule that is so certain as the optical method. For ordinary purposes, a distant object—such as a signboard, a lamp-post, or a window—should be sharply focussed on the focussing screen, using the full aperture of the quickest lens at the disposal of the operator. The screen is then turned back, and each side of each

double-back is by turn brought into its proper place, and a piece of glass with a flat and finely ground surface is held in exactly the position that the sensitive plate would occupy in making an exposure. If the image is well defined the register is correct. The same method should be pursued where greater exactness is desired, but transparent screens with fine lines on them should be used, and the focussing done by means of a good magnifier. To focus sharply and then expose and develop a plate is far more trouble and not so good a method, because the correction of the lens for chromatic aberration is included in the test.

There is great variety in camera stands, and those that appear to be cheaper are sometimes deceptive. It is useless to have legs of exceptional strength to a studio stand if they end in weakly castors, and stability in the fixed parts is wasted if the adjustable top that carries the camera is unsteady. However the top is secured it should show no signs of giving way when pressed with considerable force upon either corner; and this test should be repeated after varying the positions of the adjustable parts. Ball and socket arrangements are not to be recommended in any camera stands, because the support at that part is of necessity too small.

It is a mystery why a triangle or a minute circle should describe the outline of the majority of tripod tops when the base of the camera itself is neither triangular nor circular, and the symmetrical clustering together of the top ends of the three legs is an idea extended to camera tripods without reason and with much sacrifice of stability. The tripod top should be of about the same form, and not very much smaller than the base of the camera, and to allow of adjusting the camera by turning it round upon its screw, might have a rounded front and sides narrowed off a little towards the back. It will be found a very considerable convenience for working in country places to have the legs adjustable in length.

To ascertain whether a portable camera stand or tripod is fit for use, the largest camera that it is supposed to carry should be screwed on to it, after placing the legs in the

ordinary position. Then on taking hold of the camera it should feel as if it were one piece with the stand. The legs are generally attached to the tripod top by means of pins in the one and holes in the other, and it is the exception to find the holes to fit the pins. If the legs have sliding extensions, as much pressure should be brought to bear upon each leg as would suffice to drive it into the ground on average pasture land, and the sliding connection should remain firm. Other things being equal, the fewer joints the firmer the tripod; but the other things so rarely are equal that the fewness of joints is no indication of stability. There is probably no firmer tripod of its size than the fourfold tripod of Watson and Sons, and the firmness is due to the exact fitting of the connections obtained by stamping them out with suitable machinery.

CHAPTER III.

EXPOSURE SHUTTERS.

THOSE shutters specially made for use in the studio to add to the convenience of the operator and prevent the model from being distracted by the removal of a lens-cap are very desirable adjuncts to the camera ; but as they are simple in construction and their advantages are obvious, there is little to be said about them.

The need for shutters in general out-door work has been very much over-rated by some extravagant practitioners of the photographic art. It is not uncommon to hear the statement made, "I always use a shutter," and further inquiry generally shows that the individual who makes the announcement is one who "takes shots," as he calls it, indiscriminately. He prides himself on "developing" a large number of exposed plates in an incredibly short time, and always uses the cheapest plates, because the first cost of the plate is the chief expense of his practice. His energies are spent in making what he calls "negatives"; he does print occasionally, but only to show that his negatives "will print."

For general work, it is advisable as a rule to make two or three seconds the shortest time of exposure, and, if necessary, to use a smaller stop than might otherwise give a satisfactory result. Two seconds can be timed with quite sufficient exactness after a little experience, but a shorter exposure cannot be given with the lens cap with that certainty that is desirable. An expert hand can expose for one second, half a second, or even a quarter of a second, without the assistance of machinery; but when the lens cap is taken off and replaced with so short an interval there is likelihood of shaking the camera, and of other accidents, the chances of which may just as well be avoided. It does not appear to be possible to give a hand exposure

of less than a quarter of a second, and it is preferable for this, as well as for all shorter times, to use a shutter.

It is hardly possible to say what is the shortest exposure that it is well for a shutter to give unless the nature of the work to be done is clearly understood. Exposures of the one-thousandth of a second are desirable in some scientific experiments, and any longer time may be necessary under certain circumstances. But if a shutter is wanted for general work, and is to be carried in case of need, rather than for any pre-arranged purpose, then there is no doubt whatever that a range from one-fourth to one sixty-fourth of a second will be very useful and sufficient. If this must be curtailed, then say one-eighth to one sixty-fourth, or one-eighth to one thirty-second of a second. It is of little use to have an adjustable shutter unless the speeds under the given variable circumstances are known, hence it is convenient to have a few definite exposures that can with certainty be reproduced. Reducing these to a minimum, the eighth, sixteenth, and thirty-second of a second will be found to be a useful series.

It is as impossible to construct a perfect shutter as a perfect lens, and it is, therefore, the more important to realise what is wanted, that minor considerations may give way to that which is more important.

The shutter, when in position and fully open, must have no part of it visible when the eye is brought to the place occupied by the extreme corner of the focussing screen when in its place as if a distant view were focussed upon it. Many shutters that work in front of the lens are made to fit the hood, but the opening in the shutter is even smaller than the lens itself. In most lenses the hoods are only just large enough to be out of the way of the light, and the opening in the shutter ought therefore to be as large as the ring that fits upon the hood. Otherwise the edges of the plate have a less exposure than the centre, because the small opening in the shutter acts as a diaphragm towards them, and this evil, which cannot be altogether avoided, is needlessly exaggerated.

The whole field should be exposed simultaneously and equally, or, if one part of the plate receives more exposure

than another, it should be that part that needs most exposure, namely, the foreground.

As large a proportion as possible of the exposure should be given with the full aperture, hence the opening and closing should always be as rapid as possible, and the duration of the exposure regulated by the interval. To regulate the speed of a shutter by simply slowing or quickening its action is bad in principle, though perhaps sometimes convenient in practice.



There must be no jarring or jerking until the exposure is quite over.

And, finally, a shutter should be small, that it may not catch the wind; light, that it may not strain the lens-mount, or camera-front; simple, that it may be easily repaired by the user, quickly fixed to or removed from the lens, and need no change whatever in either the camera or lens.

With the usual form of rapid doublet there are three distinct positions for the shutter—in front, behind, and between the two combinations in the place of the diaphragm; and any shutter will vary in its effects according to which of these positions it occupies. It has been proposed to put the shutter immediately in front of the sensitive plate. If an exceedingly rapid exposure is necessary, as, for example, in photographing a bullet from a gun during its flight across the axis of the lens, this position for the shutter is to be recommended. By drawing a narrow opening across the sensitive surface great rapidity is possible, but when the subject occupies the whole plate, the entire surface should be exposed simultaneously, otherwise the picture will suffer from distortion.

The drop-shutter is largely recommended by practical workers, and it certainly is simple, uniform in action, and free from jar until the exposure is over. But this shutter never gives an even exposure: if in front of the lens, the sky has most exposure; if behind the lens, the foreground has this advantage; but a drop-shutter cannot well be worked inside the camera for want of room, and to fit it outside the camera and behind the lens means either a permanent addition of considerable weight, or an apparatus that

requires much adjusting and is otherwise awkward. The greater the distance through which the dropping piece falls before it begins to open the lens, the more even is the exposure over the whole plate. One great fault of commercial drop-shutters is that the aperture in the dropping piece is not long enough. Its length should be at least two and a-half or three times the diameter of the lens, that the duration of the exposure may not much exceed the equivalent exposure. The equivalent exposure is the time that would produce the given effect if the lens were fully open, and no part of the time were required for the operations of opening and closing.

It is easy to construct drop-shutters that are adjustable, with the advantage that the shorter exposures light the plate more evenly and the longer exposures give a greater efficiency, by making a long opening in the dropping piece, which opening may be reduced by a slide working from below. It is not a good principle to regulate the speed of a drop-shutter by varying the amount of fall, as this should always be at its maximum, because, by increasing the distance of fall, all the irregularities of the apparatus are reduced. The opening in the dropping piece must not be round or oval, or the edges of the plate will be needlessly robbed of light. A rectangular opening, passing at a uniform speed across the lens aperture, gives an even exposure over the whole surface of the lens, but as the edges of the plate are less brilliantly illuminated than the centre under ordinary circumstances, it is advisable to deprive the centre of the plate of a little of its light by shaping the ends of the opening in the dropping piece thus  (or thus 

In the flap-and-drop shutter in front of the lens, the excess of exposure is given in the right place—that is, the foreground; but when the dropping piece has its movement quickened by means of an indiarubber band, there is a very perceptible jar in the middle of the exposure, and unless the camera is of a very rigid type, the image produced on the plate will be duplicated. When the dropping piece falls by its own weight only, there seems to be no shake.

There are several shutters made on the "go-and-return" principle, a single sliding piece being drawn away to open the lens, and sent back to close it. Whatever jar results from stopping the slide and returning it takes place at the very moment when the lens is fully open. To give the excess of exposure to the foreground, the slide should move up and down if the shutter is in front of the lens, or down and up if at the back of the lens. This principle has been applied to shutters working between the lenses in the diaphragm slot, and there are some that do not require any alteration of the lens mount, the sliding piece being so thin. A drawback to this arrangement appears to be that the diaphragms are interfered with, and it is necessary and often advisable to use a diaphragm, that a gain in marginal definition may be secured when the subject is well enough lighted to allow of it. The "snap" shutter is a modification of the "go-and-return" principle, in which the sliding piece works on a pivot.

Instead of the same slide returning to close the lens, a second slide may be employed, and this principle has the advantage that the two slides may be released by means of a disc caused to revolve at a regular rate by clockwork, and that any required time interval between the releases may be secured by adjusting the two releasing catches upon the revolving disc. Addenbrooke's shutter is an example of this principle. In this form of shutter it is usual to make the opening slide fly up, and the closing slide fly down, and it will be obvious that if the second slide is released before the first has time to get to the end of its journey, the upper part of the lens will be covered by the closing slide before it is uncovered by the opening slide, and the upper part of the subject that corresponds will receive no exposure at all. This must be guarded against in endeavouring to get very rapid exposures. Another drawback to this form of shutter is that the opening slide produces whatever jar results from the stoppage of its motion at a time when the lens is fully open; but this principle has the advantage that the efficiency of the apparatus is greater with longer exposures. It is easy to make the lens-cover divide in the middle

by constructing it of two jaws like a pair of scissors, as in Watson's double-snap shutter, or to open from the centre of the lens by drawing two superimposed slides in opposite directions, each slide having a diamond-shaped hole in it, as in Sands and Hunter's. Such shutters placed either at the back or the front of a doublet lens are not to be recommended, for the inequality of illumination resulting from their use is such as to magnify the defect inherent in all lenses used with large apertures. The oblique pencils of light that go to form the margins of the picture are partially cut off by the lens, and these shutters placed as stated give the residue of the oblique rays a less time to act than those rays which form the central part of the picture. But if, as in the case of one form of the second shutter mentioned above, the central opening and closing is done at the diaphragm place, the shutter causes no change in the proportional illumination of the plate, and actually improves the definition as compared with the result of having the full aperture of lens open the whole time, because the shutter is practically an expanding and contracting diaphragm. Instead of two slides, a flexible material with the two apertures in it may be used by passing it over a roller at one end of the frame of the shutter, and it is stated that such an arrangement is useful and convenient, but it ought only to be used in the diaphragm place.

Dallmeyer has recently perfected a shutter that works between the components of a rapid doublet, and is a fixture, forming a part of the lens mount. The action is that of an iris diaphragm, opening to full aperture and closing again, so far as the visible part is concerned. The diaphragm slot of the mount is not interfered with, so that any fixed diaphragm may be used, as the choppers or leaves, which fall back to open the lens and advance again to close it, work in a plane just behind the diaphragm. The choppers are actuated by the partial revolution of an annular plate with radial slots, in which slide pins fixed to the choppers. The moving parts being symmetrically disposed round the lens are not likely to cause any jerk. Although this shutter, like the one

previously referred to, has a rather low efficiency as compared, for example, with a drop shutter that has a long opening in the dropping-piece, this must not be regarded as altogether a disadvantage, as the beginning and end of the exposure, when the shutter is only partly open, give sharper definition and a more even distribution of light over the plate than is obtained when the shutter is fully open. For a given sharpness of image a larger diaphragm may be used with such a shutter than with a shutter working outside the lens.

Rotary shutters have much to recommend them. The movement is continuous; it may be made more uniform than that of a drop-shutter, and if the margins of the revolving piece, or the opening in the disc when that is used, are drawn from the centre or pivot as radii, a very even lighting is secured. Such shutters, however, are generally large and heavy, being often made of metal, with the revolving piece as an entire disc. Paper is a material that is light and strong, and lends itself readily for the construction of rotary shutters, and by reducing the revolving piece to those parts that are actually needed for covering the lens, the apparatus may be made very compact. In making such a shutter, cardboard may be glued together until a sufficient thickness is obtained for each of the various parts.

The roller-blind shutter has been very deservedly growing in favour during the last few years. The blind is made of opaque material, and has an opening in it which is drawn across the aperture by a spring roller. This motion appears to cause no jerking, or at most a slight jar after the exposure. If properly constructed, such a shutter is light and compact, and will give a considerable range of exposures. Its adaptability to special purposes is referred to in the chapter on hand cameras.

The pneumatic release of J. W. T. Cadett may be applied to any shutter, and in its simplest form consists of a minute bellows, leading from which is a tube terminating with a collapsible ball. By pressing the ball the bellows is inflated, and by its expansion it pushes away a catch that retains the moveable part of the shutter.

It is important to be able to estimate the length of exposure given by any shutter, that the apparatus may be used intelligently. The length of time occupied in giving the exposure is, as has been pointed out, always longer than the equivalent exposure. If the shutter begins to close as soon as it is fully open, so that the whole time of exposure is occupied in opening and closing, the duration of the exposure may be assumed to be double the equivalent exposure. For example, the amount of light that reaches the plate, if equal to what would pass through the open lens in one-eighth of a second, would take a quarter of a second to get through. A good shutter that gives an exposure of a quarter of a second duration would give an equivalent exposure of nearly the same time, or, as compared with the first, nearly twice as much light, with no more blurring due to the movement of the subject during the prolonged exposure.

The duration of the exposure, and the equivalent exposure, may be, therefore, very different, and it is necessary to distinguish between them. The duration of the exposure given by some shutters can be estimated by attaching a tuning fork to the moving part, and causing it to vibrate during the exposure, and mark its vibrations on a piece of smoked glass. If an A fork is used, each vibration is equal to the 430th of a second, and in a C fork to the 256th of a second. Or by calculating from the known rate at which a body falls, the duration of the exposure given by a drop-shutter may be approximately found.

Disregarding friction, which always retards movement, but will vary according to the particular circumstances in any particular case, a body falls inch by inch in the following fractional parts of a second.

1st inch in	$\frac{1}{14}$	or	0714
2nd "	$\frac{1}{36}$	"	0277
3rd "	$\frac{1}{48}$	"	0232
4th "	$\frac{1}{62}$	"	0192
5th "	$\frac{1}{79}$	"	0169
6th "	$\frac{1}{85}$	"	0154

But it is, perhaps, better to find the equivalent exposure, and from this, and the method of action of the shutter, to see approximately what must be allowed for the duration of the exposure.

A method of estimating the practical effect of the exposure given by any shutter is to photograph a body moving at a known rate, and to measure the distance it passes through during the exposure as indicated by the impression on the plate. The thing photographed should be white against a black background, and if possible in the sunshine. A clock without a pendulum, so that its minute hand moves rapidly; a bicycle wheel with a piece of white paper attached, which can be timed to make one revolution in a second without much difficulty; a white plate allowed to fall in front of a black background graduated in white, are examples of available means of getting what is desired.

When an exposure is being measured, care must be taken to have the image of the moving object as near the centre of the plate as possible, as the edges of the plate get a less exposure, and in most shutters either the upper or lower part of the plate get an excess of exposure. This is particularly necessary with those shutters that begin the exposure and finish it at the same part of the plate, as in go-and-return and flap-and-drop shutters. In the majority of cases it is only possible to get an average result, but it is always possible to select the most useful manner of performing the experiment.

An apparatus that doubtless gives more exact results than the methods referred to above has been devised by G. L. Addenbrooke. A sensitive plate is caused to revolve at a known rate behind a small opening in an opaque screen, while magnesium ribbon is burnt in front of the screen. The shutter is fixed between the magnesium light and the screen. The proportion that the curved line produced on developing the plate bears to the whole circle is the proportion that exists between the time of one revolution of the plate and the exposure given by the shutter. If, for example, the plate turns round once in a second, and a quarter of a circle is produced on developing the plate, it is obvious that the shutter allowed the light to pass for a quarter of a second.

CHAPTER IV.

HAND CAMERAS.

The great rapidity of gelatine plates and the fact that they are always ready for use, have made it possible to work with cameras without a stand or other fixed support, merely holding the apparatus in the hand. It is obvious that any camera in conjunction with a suitable shutter may be used in this way unless it is too heavy, but the advantage of the principle is especially manifest in a small apparatus made complete in itself and that may be carried about without fatigue or the annoyance of being stared at by passers by.

The first hand cameras appear to have been described by T. Bolas, in 1881, who gives details of several forms of what he calls "detective" cameras, evidently with the idea that they would be found serviceable by the police force. He recommended that when used they should be supported upon some firm object such as a gate or post, or even the ground, but added that the exposure might be given while the camera was held in the hand. Following up the idea of using a camera in public places without recognition, the earlier patterns of several makers were designed to hide the fact that the apparatus was of a photographic character. But, obviously, the more that were made the less possible did it become to maintain the deception, and now, except in very few cases, the "detective" character of hand cameras is no longer a desideratum, and a simple and unobtrusive exterior is all that is aimed at.

Some of the earliest hand cameras were merely small landscape cameras in a box with an opening for the lens, but this is a needless addition to the weight, and it is more usual now to arrange a simple box to carry the lens at one end and the plates or film at the other. Many mechanical

arrangements have been devised for changing the plates rapidly, and for those who appreciate film negatives, roller slides are especially to be recommended.

For exact work a finder is essential. It may be attached to the camera, or it may with advantage be separate and held in position as required. The most convenient form consists of a small lens and mirror giving an exact image of the view on a ground glass screen. By means of a reflector within the camera it is possible to throw the view as produced by the operating lens upon a screen at the top of the apparatus.

The shutter is one of the most important parts of a hand camera. It may, however, be comparatively bulky without detriment, because, as a rule, there is plenty of room for it within the camera. If a roller-blind shutter is employed, the spring roller may be enlarged and great rapidity obtained; or, if the extra rapidity is not desirable, the opening in the blind may be lengthened and the efficiency of the shutter increased. For ordinary purposes it is preferable to have the shutter arranged immediately behind the lens. But if exposures of less than about the two-hundredth of a second are required, it is well to arrange the blind next the plate, and reduce the opening in it to a narrow slit. It is thus possible to get exposures rapid enough to photograph bullets as they are fired from a gun in a direction at right angles to the axis of the lens. From the tenth to the sixtieth of a second will be found to be the most convenient exposures for average hand-camera work.

Focussing with hand-cameras is effected in a variety of ways, but almost invariably by means of a scale marked according to the distance from the object. In some cases there is no focussing arrangement, but this is a disadvantage, for it is then impossible to get sharp definition of near objects. The following table, which is taken from a more extensive one calculated by Sir David Salomons, gives, for lenses of the focal lengths and apertures stated, the distances at which objects will be depicted with an equal amount of out-of-focus effect when the lenses are focussed for an object at a great distance. The actual amount of

diffusion at the distances stated will be such that points in the object will be shown as discs one-hundredth of an inch in diameter. Obviously, the definition is sharper for objects at greater distances, and less sharp for objects nearer the lens:—

Focus of lens in inches.	Diaphragm apertures.									
	f/8		f/10		f/11		f/15		f/20	
	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.
4	17	0	13	8	12	5	9	2	7	0
4½	21	5	17	3	15	8	11	7	8	9
5	26	5	21	3	19	4	14	3	10	10
5½	31	11	25	8	23	4	17	3	13	0
6	38	0	30	6	27	9	20	6	15	6
6½	44	6	35	9	32	6	24	0	18	1
7	51	7	41	5	37	8	27	9	21	0

The expression “fixed focus lens” implies an impossibility, and so far as it has any meaning must be regarded as a conventionalism, indicating that the camera will not allow of focussing adjustment, or that the lens is of so short a focal length and so small an aperture that it may be used without great inconvenience on such a camera.

Hand cameras have also been made for special purposes. As an example we may refer to Marey's gun camera, by which a series of photographs of flying birds have been taken in order to determine the actual movement of the wings. The apparatus in this case is mounted on a gun-stock, and the image of the object is kept upon the sensitive plate by sighting after the manner of taking aim with a gun.

CHAPTER V.

VARIOUS FORMS OF LENSES.

IN the earliest days of photography, before special lenses were to be obtained, it was usual to employ telescope objectives. But these lenses were ill-suited to the purpose, though their performance in a telescope might have been unexceptional, because the image viewed through the eyepiece of a telescope is smaller than the objective itself, while the picture produced in the camera is often required to cover a comparatively large area. The rays that pass obliquely through the objective in a telescope are not utilised, but in the camera the oblique rays generally form by far the greater part of the image.

To increase the covering power, the objective was turned round, and a diaphragm was put in front of it. (See fig. 16.*) But with this assistance the image



FIG. 16.

produced is not perfect enough over a sufficient area to satisfy modern requirements. The diaphragm obviously diminishes the light, and it also distorts the image, as will be subsequently shown. With such an arrangement, also, the image of a flat object is curved, like the inside of a saucer, and the chief of the light which acts photographically is brought to a focus at a considerable distance within the visible image.

* In all the figures the arrow indicates the direction of the light in passing from the object to the image; that is, the arrow points *into* the camera.

In these and in other ways the existing lenses were faulty when applied to the new art. The chief corrections desired were a larger aperture for the sake of rapidity, a larger and flatter field, and chromatic aberration corrected in an especial way, namely, the most intense of the photographically active rays brought to focus at the same point as the most intense of the visible rays, and distortion reduced to a minimum or completely eliminated.

The larger the aperture, other things being equal, the smaller the field, and so it has been found convenient to perfect lenses in two directions; some with a small aperture and therefore slow in action but covering a large field, and others with a large aperture and consequently rapid but producing a comparatively small picture. The first are classified as view lenses, the second as portrait lenses, while the lens of medium properties is called a universallens, or a view and group lens. There is nothing scientific in these distinctions. Under certain conditions a view lens is superior to a portrait lens for taking portraits, and portrait lenses have often been used for taking views. By common consent, lenses whose apertures are about one-sixth of their focal lengths are called universal, or portrait and group lenses; if the aperture is one-eighth it is a view and group or simply a view lens; if quicker than the first of these it is a portrait lens, if slower than the second a view lens. Variations from these rules will be found, but they tend to deception unless they are accompanied by an explanation.

The first improvement on the telescope objective arranged as described above was by J. Petzval, the in-

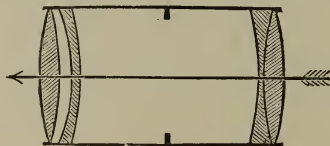


FIG. 17.

vention of whose portrait combination was one of the two epochs in photographic optics. This lens was constructed by Voigtlander, of Vienna, under Petzval's instructions, in

1841. It is shown in fig. 17. The focal-lengths of the posterior and anterior combinations are as 3 to 5, and the combinations are separated a distance about equal to half the equivalent focal length of the whole lens. The chief point about this lens is the great gain in rapidity got by shortening the focal length and using the full aperture without a diaphragm. The focal length is shortened by having two combinations instead of one, and the spherical aberration is so cured by means of the separated back combination that a diaphragm is rendered unnecessary. The multiplication of surfaces, six instead of two, causes loss of light and also adds to the diffused or false light in the camera.* It is stated that Andrew and Thomas Ross (father and son) worked out a photographic objective with separated combinations, a device suggested by Thomas Ross to gain in flatness of field, and that this lens was constructed by them shortly before the Petzval lens was introduced.

In 1857, T. Grubb introduced his "patent aplanatic" lenses. He gets a deeper separating curve between the components of the single lens by making the crown lens a meniscus, and putting it in front instead of behind the flint lens, as in fig. 18. By means of this deeper separating



FIG 18.

curve he claims that the "spherical aberration is nearly corrected," and that, therefore, a diaphragm with a larger aperture may be used than was possible with the old form of view lens.

* It was intended to give some idea at least of the angle of view of each lens—that is, the proportional extent of field covered—but this is found to be quite impossible except by an actual test of every instrument. Thus the author has two lenses of well-advertised and quite modern makes, one stated to cover 9 by 7 and the other 12 by 10. The 9 by 7 will cover 12 by 10, while the 12 by 10 lens will only cover 10 by 8; and taking the same apertures and fields, the 9 by 7 lens is far superior in definition throughout the field. On the other hand, the maker of this 12 by 10 lens does not always overstate the covering power of his lenses, for the author has another of his make which he calls 5 by 4 that will cover $8\frac{1}{2}$ by $6\frac{1}{2}$.

In 1860, J. H. Dallmeyer introduced his quick-acting single lens for stereoscopic pictures, modifying the curves as shown in fig. 19, that it may work with an aperture of $\frac{f}{10}$, and yet not suffer to a practically injurious extent



FIG. 19.

from spherical aberration. W. Wray, since 1886, has issued a series of single lenses suitable for all the ordinary sized plates, of which fig. 19 may be taken as a general representation. Rapidity is here also the especial feature, the series having a maximum aperture of $\frac{f}{10}$, except the larger sizes, which work at $\frac{f}{8}$. This last aperture, however, does not give what is commonly called a sharp picture, and is useful chiefly in large direct portraits. The introduction of a certain obvious amount of spherical aberration, with its concomitant loss of sharpness in the picture, is sometimes desirable in order to gain what could be got no other way so well. This matter is subsequently referred to.

The single landscape lens was further modified in 1864 by J. H. Dallmeyer, who uses two crown glass meniscus lenses of focal lengths as 1 to 3, and cements the flint lens between them, as in fig. 20. This gives an additional



FIG. 20.

surface for correction of the aberrations, so that it is possible to get a better correction of the oblique pencils, and it also has the minor advantage that the softer flint glass is protected on both sides. The lenses of this series have maximum apertures varying from $\frac{f}{13}$ to $\frac{f}{20}$.

In 1886, Dallmeyer issued another series of single landscape lenses of somewhat similar construction to those last described. They differ in including a smaller angle (that is, for the same covering power they have a longer focal length) and in working at twice the rapidity, *i.e.*, $\frac{f}{11.3}$. The diaphragm is, of course, larger, and it is placed further from the lens to give greater flatness of field (fig. 21).



FIG. 21.

The anterior convex meniscus is of extra light flint instead of crown, and the anterior surface of this lens is less curved than in the wide angle lens.

In 1888, the same optician introduced another landscape lens, in which the back component is curved in the opposite direction from the other two, as shown in figure 22.



FIG. 22.

The two anterior lenses are cemented, and form a combination of very long focal length. This lens is intermediate in rapidity between the two last described, the maximum aperture recommended when good definition is desired being f_{14} . The especial feature of this instrument is that it is free from curvilinear distortion, and is therefore suitable for taking architectural subjects, for copying, &c.

The desire for a lens to cover a large field stimulated J. Petzval to work out another lens particularly adapted to landscape work. In 1858, Dietzler, of Vienna, issued the new lens under Petzval's directions, for Voigtlander and Petzval had disagreed since they had worked together at the portrait lens. Petzval's fame secured an immediate

and warm reception for the new instrument, and it was copied by many opticians of repute, who christened their productions variously as orthoscopic, orthographic, caloscopic, &c. Fig. 23 shows the lens as made by the

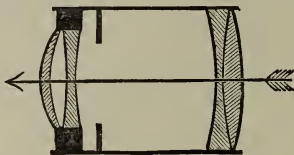


FIG. 23.

American optician, Harrison. It will be observed that Petzval has adhered to his first principle of a separated back combination, but in this case the combination is negative or diverging, and therefore makes the focal length of the whole lens longer than that of the front combination. After experience with this lens, the foremost landscape photographers of the day pronounced it not so useful to them as the single landscape lens, and found that it required a smaller stop. The orthoscopic lens gives pin-cushion distortion, but to only a slight extent as compared with the opposite, barrel-shaped distortion of single lenses with the diaphragm in the front.

In 1859, Derogy advertised a photographic objective giving in the one instrument three portrait and three view lenses, the necessary changes being made by means of bayonet joints. This *multum in parvo* method has also been adopted by Jamin, Melhuish, Darlot, the Sciopticon Company, and recently by other opticians.

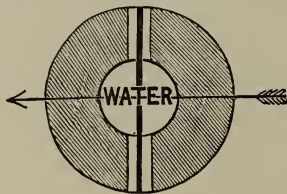


FIG. 24.

In 1859, Thomas Sutton patented his panoramic water lens (fig. 24) for use with long curved plates. It was achromatic, and from its spherical form would transmit

oblique rays almost as perfectly as the central pencil. Besides the obvious drawbacks to lenses containing fluids, such as leakage, there is the impossibility of preserving the temperature of the liquid uniform, and a change in temperature means a change in refractive power. In 1861, T. Ross bought the patent rights of this lens, and issued copies to the public. Other fluid lenses, as they are called, have been constructed.

In 1860, the celebrated triplet of J. H. Dallmeyer was constructed. This was the first lens attaining to any degree of appreciation that was specially adapted for views and copying, and gave a picture free from curvilinear distortion (see fig. 25). Its three combinations are each

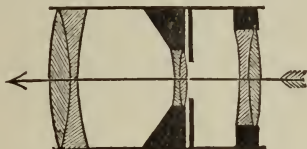


FIG. 25.

achromatic, and the central combination, which is diverging or negative, serves to flatten the field. By removing the central combination the focal length of the whole lens is reduced, and its aperture, originally $\frac{f}{15}$, is enlarged sufficiently for portraiture.

The need for a non-distorting view lens was now fairly appreciated by opticians, and within the next six years this want is catered for in a way that the subsequent five and twenty years has not been able to better.

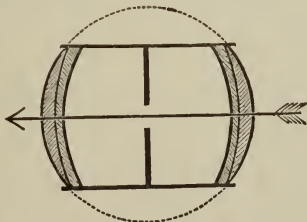


FIG. 26.

In the same year C. C. Harrison patented his "globe" lens, so called because the outer surfaces of the combina-

tions form part of the same sphere, as shown in figure 26. This lens is a symmetrical doublet, and suffers much from spherical aberration and from flare.

In 1864, Ross's "actinic doublets" were introduced (figure 27), the first non-distorting doublet including a



FIG. 27.

wide enough angle for average views that enjoyed any degree of popularity. This lens is not symmetrical, and it is free from flare. It was made in three series, rapid, medium, and wide angle, and the last pattern includes as wide an angle, probably, as any lens made before or since for use with flat plates.

C. A. Steinheil, in 1865, introduced the "periscopic" lens, a non-achromatised, symmetrical doublet, as figure 28. This lens includes an angle of 90° , and is an improve-



FIG. 28.

ment on the "globe," being about one-quarter the diameter for the same field, because the lenses are brought nearer together. It is, however, not free from flare, and its defining power was much complained of. Obviously, focussing cannot be done as usual with a lens not corrected for chromatic aberration, and to get over this difficulty the inventor states that no focussing is necessary, as near and distant objects are equally clear, and the plate-holder should be adjusted once for all. Deceptive statements of this sort had been made before, and so far as there is any truth in them, they apply equally to all good lenses of the same aperture and focal length. The periscopic lens was not a step forward towards perfection.

CHAPTER VI.

THE FORMS OF LENSES (*continued*).

IN 1866, we have the second epoch in the history of photographic objectives; for just as the Petzval-Voigtlander portrait lens has been copied by every optician who caters for photographers, so has the symmetrical achromatic doublet, working at about f_8 , been imitated; but with, perhaps, this difference, that each imitator deems it necessary to give a new name to his production, and so, as far as he is able, to introduce it to the world as a new instrument. Steinheil's "aplanats" and Dallmeyer's "rapid rectilinears" were the first lenses of this character introduced. It appears that both opticians worked simultaneously in the invention of this lens, and that Steinheil was the first to issue them to the public. Dallmeyer's lens was preceded a few months by his wide angle rectilinear doublet, working at $\frac{f}{13}$ to $\frac{f}{17}$, which has its posterior combination of smaller size than the front com-



FIG. 29.

bination, that its reflecting power may be diminished, and any tendency to flare reduced. See figure 29. The nature



FIG. 30.

of the rapid lens is sufficiently indicated by figure 30. Steinheil also introduced large angle aplanats, in which

the combinations are of smaller diameter, thicker, and very much nearer together.

The rapid rectilinear of Dallmeyer soon began to replace his triplet, but it was not till 1874 that Ross introduced his portable and rapid symmetricals, and left his actinic doublets as instruments of the past.

The apertures chosen by Steinheil and Dallmeyer, τ and $\frac{f}{8}$ respectively, have proved to be the most useful for the general work that such lenses are constructed for; but in January, 1870, J. H. Dallmeyer exhibited a lens of similar construction, and of aperture $\frac{f}{4}$, at the London Photographic Society, to show that by reducing the angle of view included, this form of lens could be made as rapid as the ordinary portrait lens. J. H. Dallmeyer considered, and the firm still consider, that this pattern is not the best for general portraiture. Voigtlander, however, has since then introduced two series of rapid symmetrical doublets, his "euryscopes" working at $\frac{f}{6}$, in 1877, and his "portrait euryscopes" with an aperture of $\frac{f}{4}$, in 1886. These more rapid symmetrical lenses have met with considerable favour, and are now made by many opticians.

At the same time that J. H. Dallmeyer obtained a patent for his wide angle rectilinear lens, 1866, he got protection for a modification of the Petzval portrait lens, in which the flint component of the separated back combination was put behind instead of in front of the crown, and the latter was a meniscus instead of a double convex lens. The new form is shown in figure 31. But the chief point

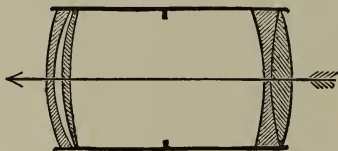


FIG. 31.

was that the back flint might be moved backwards to a certain and definite extent, thus introducing, when required, a definite and exactly reproducible amount of spherical aberration. This he called "diffusion of focus,"

a very good and perfectly descriptive term, although it has been much cavilled at.

The convenience under discussion was specifically asked for by some of the most eminent photographers; it was hailed by them when they got it as a new power, and it is still employed every day by artists who know what they want, and find this a means of getting it. Before Dallmeyer introduced this form of lens, inferior instruments were sometimes much valued, because they possessed the desired property; but in such cases the effect is due to carelessness, it is uncertain in amount, and cannot be regulated. Dallmeyer gave the possibility of getting a certain and regulatable amount that might be reproduced exactly at any time.

The advantages of the introduction of spherical aberration have been denied, but the fact that many photographers of high repute appreciate it is a complete practical answer to this objection. Its occasional usefulness was pointed

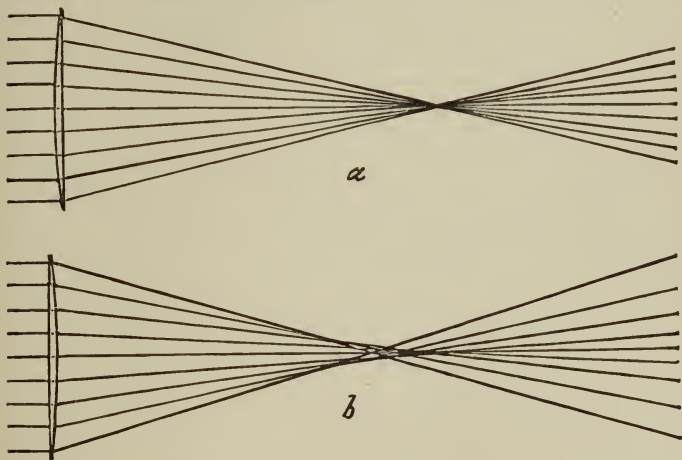


FIG. 32.

out by J. Petzval in 1859, that is, by a mathematician who was neither optician nor photographer. Indeed, he gave directions for getting a certain amount of spherical aberration with his orthoscopic lens.

The effect of the introduction of positive spherical aberration is illustrated in an exaggerated manner for the sake of clearness by *b* figure 32, *a* showing a lens of the same focal length and free from aberration. The fully corrected lens gives theoretically a sharp focal point, and represents points of objects out of focus by evenly illuminated discs. With lenses of large aperture, that is, portrait lens, this contrast in defining power for objects in different planes is occasionally very objectionable, and some artists are in the habit of putting the whole image out of focus, therefore increasing the lack of definition in every part, to get rid of the small area of painful sharpness in the picture. But it will be observed that when spherical aberration is present the sharp focal point is got rid of, and that the amount of aberration determines the degree of softness of outline in the image. Under these circumstances, however, the points of objects out of focus are no longer represented by evenly illuminated discs, but by discs which have a concentration of light at their outer part for objects nearer the lens than the plane focussed for, and discs with a central concentration of light for objects further away than the plane focussed for. In the first case the aberration narrows the pencil of light, giving depth of definition somewhat after the manner of a diaphragm reducing the lens aperture, but the outward concentration of light is a disadvantage. In the other case, however, the central concentration confers a persistence of the image as it is thrown out of focus that is sometimes remarkably great, the halo round the image increasing in extent as the object is moved more and more out of focus until the central concentration of the light dies away. It is impossible to geometrically demonstrate how much gain in depth of definition may thus be realised, because it is impossible to state where the image leaves off and the halo begins on the one side, or how much the outward concentration of light affects definition on the other. It seems very probable that the depth of definition in the presence of spherical aberration will vary according to the character of the object photographed.

Spherical aberration is present in all practical forms of

single lenses and in many doublets, and it is reduced to a negligible amount (that is, negligible for ordinary work) by the use of a diaphragm. The diaphragm reduces the aperture, and so lengthens the necessary exposure, but rapidity can be gained at the expense of sharpness of definition by enlarging the diaphragm, at the same time increasing the spherical aberration. Lenses of the type illustrated in figure 19 may have their apertures enlarged to f_8 , but with this aperture the definition is nowhere sharp, though sharp enough for large portraits.

Other portrait lenses than those already mentioned have been introduced from time to time with more or less success.

In 1874, Steinheil described a portrait lens that has both its combinations cemented, and the inner surfaces of both of nearly equal curvature, as shown in figure 33. In 1878,



FIG. 33.

Voigtlander made lenses in which the ordinary back combination of the Petzval lens was replaced by a cemented combination so constructed that both combinations had outside surfaces of equal curvature. Each combination was of the same focal length, which was two-thirds of the focal length of the whole lens. The general form of the instrument is given in figure 34. The maker claimed for



FIG. 34.

it that it avoided distortion of the image, and that it was more rapid in action and gave more depth of focus than

the original Petzval. However, in spite of this impossible combination of improvements, this construction was soon abandoned.

The greatest departure from the rules ordinarily observed by opticians in devising photographic lenses has been made by H. A. Steinheil in his "antiplanatic" lenses



FIG. 35.

for portraiture and views which were introduced in 1881. These are shown in figures 35 and 36. In both cases the anterior combination has a shorter focal length than the whole lens, and the posterior combination is diverging. The back and front combinations both suffer greatly from

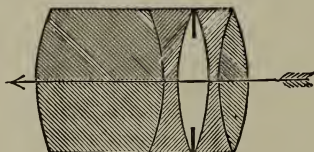


FIG. 36.

spherical and chromatic aberrations, but to an equal extent in an opposite sense, so that they form a properly corrected whole. It is claimed by the inventor that by means of this principle a better definition is secured at the edges of the field. The maximum aperture of the portrait lens is $f/3$, and of the view lens $f/5$.

In 1881, E. Abbe and O. Schott began a series of costly experiments, in which they were assisted by the German government, in order to reduce the limitations hitherto imposed upon opticians by the small variety of optical glasses at their disposal. The now celebrated optical glass works at Jena, conducted by Schott and Gen, is the practical result of these investigations. By the employment of other than the usual constituents,

this firm is able to offer more than a hundred varieties of glass, many with new and specially valuable properties. In addition to this, they are ready to do their best to make other glasses of any character that an optician may desire. By the use of some of these new glasses it is possible to reduce astigmatism, and so to get better definition at the edges of the field, and this is the chief improvement that should be looked for. Swift & Son were the first English opticians to avail themselves (in 1886) of the resources of the Jena factory for the construction of photographic objectives. Many others are now using the newer varieties of glass, and claim to have effected considerable improvement thereby. Zeiss, of Jena, has just begun to issue lenses of a novel form, but a description of them is not inserted here, as it is not yet known whether they will establish themselves as superior to the types of construction at present in use.

CHAPTER VII.

SOME OF THE PROPERTIES OF PHOTOGRAPHIC LENSES.

A PHOTOGRAPHIC objective, like every other instrument, requires skill in the using of it; and speaking generally, the better or the larger the lens is the more need is there for skill and care. In ignorant and untrained hands, an inferior lens will often give a better result than a more perfect objective, and the amount of carelessness that will do no appreciable harm when using a slow landscape lens and a small plate, would be fatal to the results on a larger plate with a rapid lens. It is especially for this reason that beginners are advised to practise at first with small cameras and comparatively slow lenses.

To use lenses intelligently and successfully, the operator must be acquainted with certain of their properties. The focal length of a lens for parallel rays is an item involved in many problems. This can be determined roughly, but near enough in most cases to identify the lens from the maker's catalogue, by focussing a distant object and measuring the distance between the ground glass and the back surface of the lens if the lens is a single combination, or between the ground glass and the diaphragm if it is a doublet.

But by taking advantage of the fact that the focal lengths of non-distorting lenses are proportional to the linear dimensions of the images that they give, it is easy to formulate a method that is practically exact and convenient, especially when several lenses have to be tested. For this purpose it is required to have a lens of known focal length, or a thin spectacle lens will serve as the standard, because, being thin, it is easy to measure the distance between it and the screen, upon which it produces a sharp image of distant

objects. The spectacle lens used must not be a meniscus, and to be most exact it should be a plano-convex, with the convex side towards the screen, when the distance between the convex side of the lens and the focussing screen is the focal length sought. To use such a standard lens, the distance between the sharply-focussed images of two objects that are far enough away to be in focus at the same time that the horizon is sharply represented is determined, and the distance between the images of the same objects is measured, using each of the lenses to be tested in its turn. The proportions that exist between these distances are also the proportions that exist between the focal length of the lenses.

An exact, though practically more awkward, method is to mark the positions of two sharply-focussed images on the ground glass, and then to substitute a piece of tinfoil or a card with a small hole in it for the lens (or perhaps the smallest diaphragm of the lens itself will answer if the combinations are removed), and to get the two images produced by the simple hole to exactly correspond with those produced by the lens. The distance between the small hole and the ground glass is the focal length sought.

Though these methods are not strictly exact when applied to lenses that give curvilinear distortion, they may for photographic purposes be assumed to be exact, because it is the size of the image rather than the focal length that is important to the photographer.

If a sheet of printed matter or its equivalent is sharply focussed under such conditions that its image is exactly the same size as the original, the distance between the ground glass and the printed sheet will be four times the focal length of the lens employed. This method gives a result near enough for practical purposes, but the figure so found is rarely more than an approximation to the real focal length. The reason of this will be apparent when we come to consider the optical centres, &c., of lenses. A theoretically correct figure is obtained by focussing as above, and then noting the distance that the ground glass has to be moved forward to get a sharp image of the

horizon, or some object so far away as to be equivalent to it.

Perhaps, of all methods, the one that is at the same time the most convenient and exact is to first focus sharply at the centre of the focussing screen any convenient object that is distant enough to require the focussing screen in the same place as if a star were focussed. The position is marked upon the baseboard. A graduated rod, such as a millimetre measure, is then set up immediately opposite to the lens and at right angles to its axis, and is sharply focussed at the centre of the screen. The number of divisions of the scale included between two fine marks previously made upon the ground glass is then carefully observed, and the distance between the marks is measured by the scale to get the exact proportion between the linear dimensions of the image and the object. The distance between the last and the first position of the focussing screen is noted, and this distance bears the same proportion to the focal length sought that the size of the image of the scale bears to the scale itself. The more nearly the image of the measure approaches the size of the original the more exact is the determination likely to be. By working in this way one gets over the difficulty of having to measure the image on the ground glass by applying a scale or compasses to the outer surface of the glass, and of getting in exact focus an image of an exact and predetermined size. This method is concisely expressed by the formula

$$f = \frac{s}{i} d$$

in which f is the focal length sought, s is the actual length of that part of the scale that gives the image between the marks on the screen, i is the length of the image, and d the distance that the front or back of the camera is moved over between the two focussings.

When two lenses are used together, as in the ordinary doublets, the focal length of the combination can be determined by the above methods; but it is also possible to calculate the focal length of the whole from the focal lengths of its constituents, and the distance between the

optical centres of the lenses. The actual distance between the lenses is of no use in the calculation, and it becomes important to note this, because sometimes the "separation" of the lenses is spoken of in this connection without further explanation. In a certain wide angle doublet the author finds the distance between the lenses to be a quarter of an inch, while the optical centres of the components are more than two and a half inches apart. To calculate with the lesser figure would give a worse than useless result. The formula for this calculation is

$$f = \frac{a \times b}{a + b - s}$$

in which a and b are the focal lengths of the two lenses respectively, s the distance between their optical centres, and f the focal length of the combination. Putting the formula into words, the product of multiplying the focal lengths of the two lenses together is to be divided by the sum of the focal lengths added together minus the distance between their optical centres.

It follows from the above that the focal length of one of the lenses can be calculated if the focal length of the other, the focal length of the whole combination, and the separation are known. Using the symbols in the same senses as above—

$$a = \frac{f(b - s)}{b - f}$$

But perhaps the problem in this connection that most often presents itself in practical photography is to find the focal length of one constituent of a symmetrical doublet. It is a common statement by makers that either lens of such a combination can be used alone as a single view lens, its focal length being "about double that of the complete lens." This is the roughest approximation, often an inch or more in error in the smallest lenses. The following figures give in the first column the equivalent focal lengths in inches of the complete lens, and in the second column that of the back constituents. The first and third are wide angle lenses, the second and fourth rapid lenses.

4.4	.....	7.8
5.8	.....	10.4
7.8	.....	14.2
12.9	.....	22.7

It is a nearer approximation to say that such lenses as are generally used for small plates have the focal length of one constituent equal to an inch or an inch and a half less than twice the focal length of the entire lens. But if the focal length of the lens, and the distance between the optical centres of its components are known, and assuming that the components are of equal focal length, as they ought to be, the focal length of one component can be calculated from the following formula, in which a is the focal length sought, f the focal length of the entire lens, and s the separation of the constituents :—

$$a = f + \sqrt{f(f-s)}$$

Or in words, by subtracting the separation of the constituents from the focal length, multiplying this figure by the focal length, taking the square root of the figure so obtained, and adding this to the focal length, we find the focal length of one constituent of a symmetrical doublet lens.

Every lens or combination of lenses has an optical centre, and one of the chief properties of this point is that rays of light passing through it are not deflected, but pursue paths parallel to their original paths. It is often stated that the optical centre is the point of the lens from which

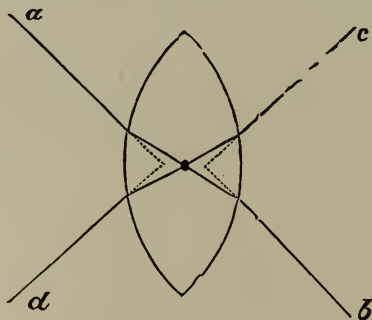


FIG. 37.

must be measured the distances of object and sensitive plate in copying to exact scales, but this statement is not quite true, especially in the case of thick lenses. The

optical centre is also the mechanical centre or the centre of gravity in symmetrical lenses, and it will be convenient to approach this subject by first studying a thick double convex simple lens. In fig. 37 the optical centre is indicated by a dot, and $a b, c d$, are rays passing through the optical centre. By continuing within the lens the direction of the rays outside the lens, as is done by the dotted lines, two points are obtained which are called respectively the points of admission and emission. It is from these points that all measurements must be taken in calculating distances for enlarging or reducing to scale. These points

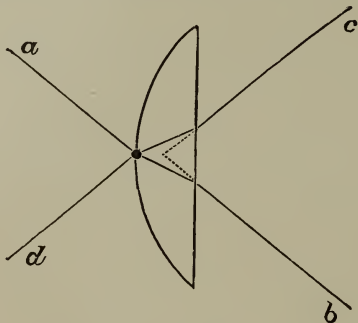


FIG. 38.

owe their existence to the thickness of the lens. In estimating the focal length of such a lens by taking a quarter of the distance between an object and its image produced of equal size, we get too high a result, because the distance between the points of admission and emission is not excluded.

The position of the optical centre of a single lens can be determined by setting out a section of it and drawing a line from the centre of curvature of each surface to its corresponding curve in such manner that the two lines are parallel. A third line is then drawn through the points where the curves are cut by the radial lines, and the optical centre is that point where this third line cuts the principal axis. In figure 38 this method is shown with a double convex lens and a meniscus. The optical centre of a plano-convex is on the curved surface; in the case of a meniscus it is outside the lens altogether. In using a single landscape lens, therefore, the distance between the back of the lens and the focussing screen is equal to or greater than the equivalent focal length of the lens; and as with a doublet this distance is considerably less than

the equivalent focal length, a given limit of camera extension may leave a margin with the latter lens, but be an inch or two too small for the former, though the focal lengths of both lenses are the same. In those cases where the optical centre is on the surface of the lens or outside it, the optical centre is identical with the point of admission or emission, as the case may be, and the position of the other point can be determined in the same way as



F G. 39.

before, as shown in fig. 39. Here *a b* and *c d* represent rays passing through the optical centre, and the dotted lines indicate the point of admission or emission that is not identical with the optical centre.

CHAPTER VIII.

THE USE AND EFFECTS OF LENSES.

THE rapidity of lenses is always comparative, and depends entirely upon the intensity of the light transmitted by the lens to the surface that receives the light, and the extent of surface that this light is spread over. The following are the chief items, which, as they increase, diminish the intensity of the light, and therefore the rapidity of the lens : The thickness of glass, the colour of the glass, the number of surfaces of glass (as each surface in contact with the air causes loss of light by regular reflection as well as by reason of the irregularities of its surface), and the distance that the sensitive surface is from the lens. Increase in the aperture of the lens gives an increase of rapidity.

It is only the last two of these controlling circumstances that can be estimated with certainty, and as these two items are by very far the most important, it is usual to have regard to only these in stating the rapidity of a lens. It should be distinctly understood that rapidity is not influenced by focal length directly, and that focal length has nothing to do with rapidity except that under certain circumstances it decides the distance of the sensitive surface from the lens. Speaking practically, we may say that in copying, and in portraiture, the sensitive surface is never placed at the principal focus of the lens, and in these cases, therefore, the focal length has nothing to do with the rapidity.

Other things being equal, rapidity is inversely proportional to the square of the distance of the sensitive plate from the lens ; and this statement may be varied by saying that the rapidity is inversely proportional to the area of the image, or to the square of its linear dimensions.

In comparing the rapidities of various lenses without reference to any special work, it is convenient to assume that the surface that receives the image is so placed that the principal focus of the lens is situated upon it. Hence we have the statement that the rapidities of lenses vary inversely as the squares of their focal lengths—a statement true enough in the abstract, but true practically only when the sensitive surface is situated as stated above.

The rapidity of a lens—that is, the amount of light which it transmits—is directly proportional to the area of the lens, or of the diaphragm when that is smaller than the lens. As there is no simple way of measuring the areas included by circles, and as such areas are proportional to the squares of their diameters, the square of the diameter is a more useful comparative expression than the area.

The actual aperture of a lens is greater than the opening of the diaphragm when this is behind a lens, as in portrait combinations and doublets in general, because the lens condenses the light. But the actual size of the opening in the diaphragm is quite near enough for practical questions connected with exposure, because the loss of light by reflection from the extra surfaces when two combinations are employed instead of one probably nearly compensates for the slight gain by the condensing effect of the front component.

It is convenient to combine these two chief items, that is, the distance of the sensitive surface from the lens (assuming this to be the focal length of the lens) and the aperture of the lens, to get a single figure that shall express the proportional exposure required. Other things being equal, the exposure must be directly proportional to the square of the focal length, and inversely proportional to the square of the diameter of the aperture; and therefore by dividing the first figure by the second we get the single figure desired. It is more convenient, however, to avoid the two squares, and the use of such high figures as these would result in, by dividing the focal length by the aperture, and squaring the result.

It has become usual to express the diameter of the

diaphragm, not in actual measurement, but as a fractional part of the focal length. Thus an aperture of $\frac{f}{4}$ is an aperture that has a diameter equal to one quarter of the focal length of the particular lens that it is associated with. This custom is convenient and reasonable, as it indicates at once the rapidity of the lens. Under otherwise uniform conditions the exposures required are proportional to the squares of the denominators of these fractions.

The standard unit aperture of the Photographic Society of Great Britain is $\frac{f}{4}$, other apertures being made each of half the area of the next larger size. The diaphragms are marked thus:— $1\frac{f}{4}$, $2\frac{f}{5.6}$, $4\frac{f}{8}$, $8\frac{f}{11.3}$, $16\frac{f}{16}$, $32\frac{f}{22.4}$, $64\frac{f}{32}$, $128\frac{f}{45.2}$, $256\frac{f}{64}$. The number that precedes the fractional expression indicates the proportional exposures and are obtained by squaring the denominator of the fraction and dividing by 16. T. R. Dallmeyer has introduced a system in which the denominators of these fractional expressions are squared and divided by ten.

What is called, in common language, "depth of definition" is practically necessary, though in an absolute and optical sense it is an impossibility. In all photography, except copying from flat surfaces, it is necessary to delineate objects that are at different distances from the lens, and objects which therefore cannot be all in focus simultaneously. In portraiture the ear and the hair must be represented as well as the nose, and in landscape work the foreground and the distance are generally taken at the same time on the same plate. To gain these ends something must be sacrificed.

In discussing this matter it is necessary to leave altogether the optical definition of focal points, and to determine the maximum amount of out-of-focus effect that shall be accepted. The usual standard allows that what should be a point may be a spot the one-hundredth of an inch in diameter, and therefore that what ought to be a line (that is, length without breadth) may be a gradual shading or vignetting one-hundredth of an inch in width. This standard, however, is only arbitrary, but it is useful, because tables have been calculated showing the actual amount of depth of definition under varying circumstances without

exceeding this amount of diffusion of focus. Such a table is given in the chapter on hand cameras. Depth of definition varies inversely as the diameter of the aperture, so that a given proportional increase in depth of definition gained by reducing the aperture requires an increase in exposure corresponding to the square of the gain in depth. For example, by halving the aperture diameter the depth of focus is doubled, but the exposure must be four times as great as before. Depth of definition also varies inversely as the square of the focal length for the same rapidity, or inversely as the focal length for the same aperture.

These rules are all based upon the assumption that an equal amount of out-of-focus effect is allowable in all cases. This assumption is justifiable in dealing with the smaller sizes of pictures that are made for direct viewing, because it is usual to hold such photographs at about the same distance from the eye irrespective of their size. But for larger pictures, or for negatives that are to be enlarged, these rules are not always applicable. It is obvious that if a 4×3 print has the full out-of-focus effect allowable, an enlargement of it to 8×6 will have twice as much as the maximum permissible blurring. In such cases it may be useful to regard the permissible out-of-focus effect as proportioned to the scale of the picture, so that negatives of all sizes taken of the same subject from the same position, shall, if reduced or enlarged to the same size, show an equal blurring.

Assuming these conditions, then depth of definition is dependent only upon the absolute aperture, and is independent of the focal length of the lens.

Ease of focussing, other things being equal, depends upon depth of definition, hence the great advantage in using lenses of short focal length in the matter of focussing, and the reason why beginners should always practise at first with small plates, and the lenses suitable for them.

This naturally leads us to the consideration of the effects of the focal lengths of lenses upon the picture produced. We hear much of the advantages of long focus lenses for ordinary use, and of the utility of short focus lenses in confined situations, of the "false perspective"

given by short focus lenses and so on. These results are, one and all, due, not to the focal length of the lens, but to the point of view selected, and that is the position of the lens with regard to the object. Every lens in the same position will give the same picture to the extent that the lens is able to define (disregarding for the moment the curvilinear distortion produced by certain view lenses), and the focal length of the lens will influence nothing but the proportional size of the representation of the object. But when the photographer has only one lens and determines to make the picture cover the plate used, he wanders to and fro with his camera until this condition is fulfilled, and then makes the focal length of the lens the excuse for many shortcomings. The point of view ought to be selected without any reference to the lens, then, if the picture desired more than covers the plate, it is impossible to secure the subject without a lens of shorter focal length which will give the picture on a smaller scale. But if the desired view as reproduced is anything smaller than the plate, it may obviously be secured. Uniformity of size in pictures is impossible without an assortment of lenses, unless the operator aims at producing mere photographs rather than pictures; but by varying the size of the pictures as occasion requires, one lens may be sufficient.

If the point of view, the amount of subject to be included, and the size of the picture are determined, there is only one focal length of lens that will give the required picture. As defects in these matters are commonly referred to the lens, though they are only associated with it and not dependent upon it, it will be convenient here to refer briefly to the nature of the most important drawbacks to certain undesirable procedures in determining the point of view and the angle of view.

The perspective of a picture as produced by any ordinary non-distorting photographic objective is correct when proper care is taken to keep the sensitive plate perpendicular, and will appear to be correct when viewed from a point having the same relation to the picture that the lens had during the exposure; but the picture will not appear exactly true to nature when looked at from any other point.

The same limitation extends to pictures of every sort that represent solid objects. The skilful hanging of pictures makes it at least possible for the spectator to see them as they ought to be seen—though even this is not possible in ordinary galleries.

It is customary to look at a picture as nearly centrally as possible, unless there is some special object to draw one's attention to it, in which case that object will probably be placed opposite the eye; therefore, the lens should be opposite the centre of the plate, so far as the possibility of moving it in a horizontal direction is concerned, unless there is a point of interest so strongly marked that it causes the attention to be concentrated upon it, when the lens may with advantage perhaps be brought opposite, or nearly opposite, the centre of interest. A picture under examination is not conveniently brought nearer to the eye than a distance equal to its greater dimension, and is more often viewed from a greater distance. Therefore, the shortest focal length of lens used should be equal to the greater dimension of the plate, except only in those cases where a subject must be taken that it is impossible to secure without using a lens of shorter focal length. There is no fear of using a lens of too long a focal length.

By changing the point of view new features are often brought into sight, as in the very simple case of a building with a sloping roof. The operator at *a*, in fig. 40, will

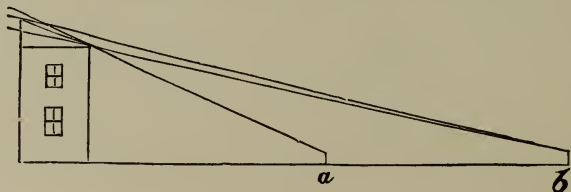


FIG. 40.

get no indication of the roof in his picture, but by retiring to *b* he will get this desirable addition. His picture at *b* will be on a smaller scale unless he uses a lens of longer focal length.

The distance that the camera is from a model in portraiture is an exceedingly important item in securing a

pleasing likeness. In fig. 41 there are two vertical lines joined by a horizontal line, the simplest expression of the contour of a sitting figure. The near point of view (*a*) causes the horizontal line, or lap of the model, to cover a very much larger space in the picture than when the point of view is shifted to a more suitable distance (*b*). The same proportions can be got by lowering the near point of view, but this would entirely alter the appearance of the face, showing the underside of the nose, &c.

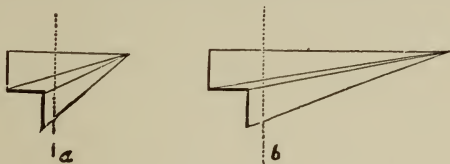


FIG. 41.

Anything round—such as a ball, a column, a face, or a limb—shows a greater extent of surface from a distant than from a near point of view, as shown in fig. 42. Such objects have, therefore, an appearance increasing in fulness and richness as we retire from them until other matters

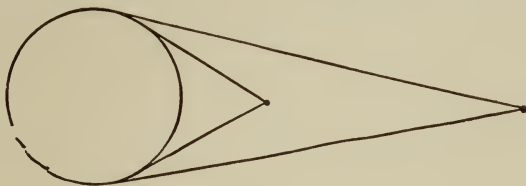


FIG. 42.

interfere (loss of visible detail from the smallness of the image produced, loss of detail from mist in the air, &c.)

There is a distortion always present when an image is produced by a lens or a pinhole upon a flat surface, because the surface is flat. Considering the picture as bounded by a circle, this distortion is an abnormal increase in size in the direction of radii of the circle, and the distortion increases rapidly as the distance from the centre becomes greater. This distortion is more marked, therefore, when a wide angle is included. A colonnade or an

avenue of trees of equal girth will be represented as if those whose images are produced on the edge of the plate were stouter than those near the middle. Fig. 43 shows this effect, and at once makes clear the reason of it. If a statue is reproduced at the edge of the plate it will appear stouter in proportion to its height than it really is. If the eye is brought to exactly the right position in viewing a picture so produced, these discrepancies disappear, and, indeed, are necessary to properly represent the object; therefore this distortion is only an evil when it is so exaggerated that it is practically impossible to see the picture from the proper point, or when the effect is detectable as a fault to the trained eye. This effect may be eliminated by means of a plate of glass with parallel sides, put conveniently between the lens and the sensitive plate; but for practical purposes it is better to avoid the trouble by not including too wide an angle in the picture.

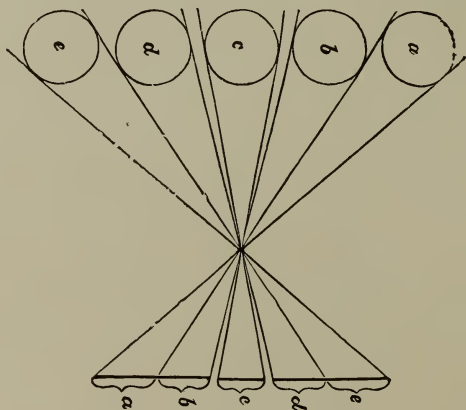


FIG. 43.

When a single lens is employed in practical photography, it is necessary to use a diaphragm either in front or behind the lens to get the necessary definition over the required surface. But by the use of this diaphragm the edges of the picture are produced by the edges of the lens, the centre of the picture by the centre of the lens, and so on. We have already seen that the refracting power of a

lens for rays parallel to its principal axis is nothing at its centre, and increases towards its edges, and it follows, therefore, that the image is displaced *towards* the centre of the screen, according as the part of the lens that produces it is further from the centre of the lens when the diaphragm is in front, or *from* the centre of the screen when the diaphragm is behind the lens. In the first case, the corners of the image of a square are drawn in, and barrel-shaped distortion results, fig. 44 *a*. In the second case, the corners of the square are drawn outwards, and the distortion is pincushion shaped, fig. 44 *b*. There is no distortion of lines in the image that pass through the centre of the screen opposite the lens—that is, lines that cross the principal axis of the lens, because the distorting effect takes place lengthwise, and lengthens or shortens, but cannot bend them.

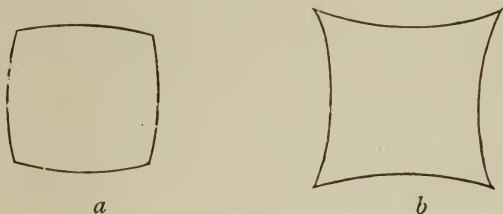


FIG. 44.

This curvilinear distortion is obviated by having a lens on each side of the diaphragm, because the distortion produced by the diaphragm with regard to each lens is opposite in character, and can easily be made equal in amount. This is the principle of the rectilinear or non-distorting doublets now so largely employed.

It is important to notice that the curvilinear effect is not the essence of the phenomenon, but merely the most obvious and striking result of it. The whole picture is drawn towards or from the centre to an extent which increases according to the distance from the centre. The bending of straight lines that do not cross the principal axis of the lens is merely due to the fact that such lines are not throughout their length equidistant from the centre of the field of the lens.

PART III.

PROCESSES.

CHAPTER I.

GELATINO-BROMIDE NEGATIVES. EXPOSURE.

THE first step towards the making of a negative used to be the preparation of the plate; but now that gelatino-bromide plates can be made with such certainty, and are prepared in such enormous quantities at very reasonable prices, it is not advisable for the photographer to prepare his own plates, unless, indeed, he is a plate-maker as well as a photographer.

The first step towards the making of a negative now is, therefore, the exposure of the plate. The use of lenses has already been described, and also the variations in exposure needed under different circumstances in connection with the lens, but there remain three items to be settled before the necessary exposure can be known, namely, the rapidity of the plate, the intensity of the light, and the darkness of the object to be photographed. It is preferable to estimate the general intensity of the light as an independent item because it varies so considerably, and it is not generally difficult to estimate the exposure needed for scenes of differing characters under a light of uniform intensity.

The rapidity of a plate is not a fixed matter that can be readily determined. Warnerke's sensitometer is the usual instrument employed for this purpose, but its indications are not to be relied upon in the absolute way that is sometimes imagined. The nature of the light affects the comparative sensitiveness of plates, and it does not follow

that because two plates are equally sensitive to the phosphorescent light of the sensitometer they will be equally sensitive to daylight. Plates equally affected by daylight may not be equally sensitive to gaslight. And this may be even pushed a step further, and we may say that equal sensitiveness on a bright day will not of necessity lead to equal sensitiveness on a dull day, because the character of the light is not the same. If the exalted sensitiveness chiefly concerns the green and blue constituents of daylight, it will suffer less from aerial fog than if the sensitiveness were increased specially towards the violet and ultra-violet.

The following short table will be found useful as giving the average proportional exposures needed for different subjects, and the times given are suitable for what are generally known as extra rapid plates with a lens aperture of $\frac{f}{16}$ with a good summer light. But the especial value of such a table lies in the fact that it gives an idea of the *proportional* exposures necessary :—

Sea and sky	- - - - -	$\frac{1}{50}$ second.
Landscape	{ little or no foreground -	$\frac{1}{20}$ „
	{ to dark foliage foreground -	$\frac{1}{2}$ „
Under trees	- - - up to	30 „
Buildings	- - - - -	$\frac{1}{5}$ „
Interiors	{ well lighted - - -	30 „
	{ to badly lighted - - -	10 minutes.
Portraits out of doors	- - - - -	1 second.

The most difficult matter of all is to estimate the photographic value of the light at the time the exposure has to be made. It is impossible to do this in a direct manner by mere observation, because the chief part of the photographically useful light is not visible, and because the eye will not serve to estimate even the visible part of the light with an approach to accuracy, unless the two lights to be compared are simultaneously in view. The eye spontaneously tries to adjust itself to light intensity, and of

itself, therefore, it reduces the difference between the impressions that would otherwise be received from lights of different value.

To measure the value of the light by its darkening effect upon a piece of ordinary silver paper is not an exact method, but the sensitive paper has no power of self-adjustment, and that part of the light that affects it is much more nearly allied to the light that affects the gelatino-bromide plate than the merely visible part of the light. As the silver paper is affected by a smaller proportion of the visible rays than the gelatino-bromide plate, it should be used as a guide to exposure only when daylight is being used ; and when the light is very poor because of mist, or when the sun is low, the exposure of the plate must not be increased in the proportion that the slowness of the action upon the silver paper would indicate. For example, if the paper blackens to a standard tint in one minute, and at the same time an exposure of two seconds is suitable for a landscape, and subsequently the paper requires fifteen minutes to darken to the same tint, the proportional thirty seconds would be unnecessarily long ; perhaps twenty seconds would be more nearly what is required. One of the best actinometers for use in the field is that attached to Watkins's exposure meter, because the sensitive material is silver bromide, and its darkening by exposure is very nearly proportional to the light effect upon an ordinary gelatine plate.

If an actinometer is not at hand, the lower the sun is the longer must the exposure be, and it will be useful to bear in mind that in clear weather in December at midday exposures may be four or five times what they are in summer under otherwise similar conditions. When in doubt give the maximum, not the minimum, exposure that is deemed suitable.

The change that the light effects in the sensitive film of the plate is obscure, and the chief fact known about it is that the developer will rob the silver of its bromine where the light has fallen upon the film, while the developer is unable to effect this change in a reasonable time where the light has not preceded it. Hence we may say that the

practical result of the action of light is to loosen the attraction between the silver and the bromine.

Two theories have been suggested to account for this. First, that the action of light is nothing more than to make the silver compound less stable; that after the action of light it is a compound containing the same proportions of silver and bromine as before, but in some way less firmly combined. Such a change as this would be a physical change as distinguished from a chemical change. The second theory suggests that a small part of the bromine is actually split off from the silver by the action of light, and that the decomposition being started it is facilitated.

Many facts have been accumulated which bear more or less upon this question. Carey Lea showed in 1887 that the effect of light that makes development possible might be transferred from one compound of silver to another. If, for example, a film of citrate, benzoate, tartrate, or pyrophosphate of silver is exposed to light under a negative, the film is developable even after it has been treated with hydrochloric or hydrobromic acid, and the silver consequently changed into the chloride or bromide. Indeed, the haloid salt produced is more susceptible of development than the original salt.* He also showed that by touching a haloid salt of silver with sodium hypophosphite, it was made amenable to the developer as if light had acted upon it. But these experiments do not prove that light in producing a developable image produces a chemical decomposition.

The theory that the light produces no chemical decomposition is upheld by the fact that the amount of decomposition (if any) is not only too small to be detected by the analytical balance, but it is too small to be detected by the visibility of the decomposed products, and this change of colour is very far more delicate than the balance. But, further, it appears that we should need a method of testing some thousands of times more sensitive than this

* This "image transference" was done in 1881 by Eder and Pizzighelli. A chloride of silver plate was exposed, soaked in potassium bromide solution until only bromide of silver remained, then well washed and developed. Eder says—"The latent image, which previously was of chloride of silver, was not destroyed, but changed into an analogous bromide of silver picture."

colour test to recognise the decomposition (if any), because it is so exceedingly small in amount.

But even such a minute amount of decomposition would be conceivable and possible, although not proved, if there were no reason for doubting it. If the action of light is to decompose a part of the silver salt, its action is analogous to that of the developer, and it would be reasonable to expect that a prolonged exposure would quicken development. But by continuing the action of light it will be found that development is facilitated up to a certain point, that with further action of light the possibility of development dies away, that more light causes it to come again, and so on. The reversing action of light, as this is called, is often manifest in the thinness of skies in negatives.

It should be borne in mind, however, that light is not homogeneous, and that its chemical effects sometimes vary according to its wave length. There may, therefore, be more than one change going on during the exposure of a gelatino-bromide plate. And it is possible that the nature of the developable image varies; it may be different on a gelatine dry plate from what it is on a wet collodion plate, and again different when a Daguerreotype plate is employed. The actual effect of light when it produces a developable image remains to be discovered.

CHAPTER II.

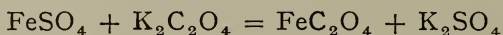
GELATINO-BROMIDE NEGATIVES. DEVELOPMENT WITH FERROUS OXALATE.

THERE are two methods of development at present in vogue for gelatine plates, the reagents used being ferrous oxalate in the one case and an organic reducing agent in conjunction with an alkali in the other. The first method is undoubtedly the simplest, but the second is certainly the most generally useful.

Ferrous oxalate is a yellow powder obtained by warming a mixture of solutions of ferrous sulphate and oxalic acid. Chemically expressed it is oxalic acid ($\text{H}_2\text{C}_2\text{O}_4$) with its hydrogen replaced by iron (FeC_2O_4). It is practically insoluble in water, but dissolves to a certain extent in solutions of alkaline oxalates, that is, the oxalates of potassium, sodium and ammonium. Of these the oxalate of potassium is preferred, because it yields a stronger solution than either of the others. The oxalate of potassium used must be the neutral oxalate, and this salt as purchased may be sufficiently distinguished from the other oxalates of potassium by its turning reddened litmus paper blue. For use a saturated solution of potassium oxalate is required, and this is conveniently prepared by shaking the powdered salt with three times its weight of water. This solution will be alkaline, and should be made just acid by adding a strong solution of oxalic acid drop by drop as required, or a little of the finely-powdered acid itself. The solution is then filtered, and will keep indefinitely.

The most powerful developer is made by adding solid ferrous oxalate to the boiling solution prepared as above, until no more is dissolved, and allowing the solution to cool in well-corked bottles. Or, instead, the yellow oxalate of iron may be shaken with the cold potassium oxalate solution at intervals during two or three days. But the

most convenient form of this developer, though weaker than either of the above, is made without the prepared ferrous oxalate at all, by simply adding a slightly acidulated solution of ferrous sulphate (FeSO_4) to the potassium oxalate solution. The maximum amount of the saturated ferrous sulphate solution is about one-third the bulk of the potassium oxalate. If this amount is exceeded there is not a sufficient excess of potassium oxalate to hold in solution the ferrous oxalate that is formed, and a yellow deposit of ferrous oxalate is likely to disfigure the negative. It is much to be preferred to always use at least four times as much potassium oxalate solution as of the ferrous sulphate solution. When these two salts are mixed the following reaction takes place:—



The potassium sulphate is useless, but appears to be inert, and the ferrous oxalate produced is kept in solution by the large excess of potassium oxalate present.

In the actual development of landscape negatives, it is better to add the ferrous sulphate solution in smaller portions, beginning, say, with a quarter of the whole amount that it is allowable to add; but there is no need for this precaution if the exposure is known to be suitable for the prepared developer, as is generally the case in portraiture, copying, &c. If, however, the operator wishes to make the very best of any negative from nature, portrait or landscape, he must begin with a weak developer, so that the detail in the most illuminated parts may be well developed, and then gradually increase the strength of the developer to suit the shadows; otherwise the detail in the lights will be sacrificed more or less by over-exposure, as the clouds often are in ordinary landscape photography.

For outdoor work, a little potassium bromide is generally necessary as a restrainer, but it must be sparingly added except when exposure has been needlessly prolonged. It may also be used in studio work, though some operators consider that a finer quality of negative is got if it can be dispensed with. The way in which potassium bromide acts is not known, but it seems probable that it attaches

itself in some way to the bromide of silver, and so makes the molecules heavier, more stable, and more difficult to attack by the developer.

A maximum of about ten drops of a two-grain solution of hyposulphite of soda may be added to each ounce of the developer in cases of under-exposure. The action of the sodium hyposulphite in this case is unknown, but it may be that by its solvent action upon bromide of silver it brings this into a more intimate contact with the developer. Other explanations have been suggested, but they do not appear to meet the case.

It has been stated that the hyposulphite of soda does not secure any detail that could not be got without its aid, and that therefore it only compensates for under-exposure in an indirect way. That its action is to quicken development, and hurry out the dark detail before the high lights have had opportunity to get too dense. Granting this to be so, it is a cure for the hardness generally characteristic of under-exposed negatives rather than for under-exposure itself, but others state that they find it most potent in bringing out detail that could not be developed without its aid.

The action of the ferrous oxalate upon the silver bromide is expressed by the following equation :—

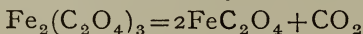


and as the ferric salts produced have a directly opposite action to the ferrous salts, the developer does not merely lose strength as it is used, but the amount of restrainers increase at the time when they ought, for a perfect result, to diminish.

It is possible to strengthen the developer as the work proceeds, by adding the ferrous sulphate in portions as mentioned above, or an old developer may be used to start with, and this may afterwards be replaced by the new and energetic developer. These methods, however, are not practically convenient, and they do not appear to be much used.

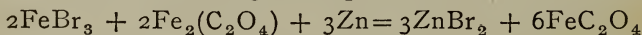
As the development results in the production of ferric salts, and as these ferric salts have the exactly opposite action that the original ferrous salts have, it is obvious that an exhausted developer contains still a large amount of

ferrous compounds that would be useful if they could be got away from the solution. There is no ready way of separating them, but it is possible to reduce the ferric salts to the ferrous state, and so not only stop their harmful action, but render them in considerable measure available for use over again. By exposing the old developing solution to light the ferric oxalate is decomposed into ferrous oxalate and carbonic anhydride, thus :



This action is slow because the red colour of the solution hinders the chemically active light from penetrating into the bulk of the solution.

Metallic zinc may also be used to regenerate the developer. It takes from the iron the bromine that has been added to it during development, thus :



The zinc acts rather slowly and produces its effect upon only those parts of the solution that are in immediate contact with it; therefore the zinc should be clean and its surface extensive. The bromide of zinc produced will not remain as such, but will probably cause a white deposit of oxalate of zinc, leaving the bromine in combination with the potassium. Thus the regenerated developer is not brought back to its original condition; it has an additional amount of restrainer. Some operators like old developers because they give brilliancy, though they hesitate to add a restrainer to a new developer; they like the effect of the bromide when they do not know that it is present.

CHAPTER III.

GELATINO-BROMIDE NEGATIVES. DEVELOPMENT WITH PYROGALLIC ACID.

DEVELOPMENT with pyrogallic acid ($C_6H_3(OH)_3$) in solution with an alkali has the advantage of giving the operator more power to vary his developer to suit the peculiarity of his subject, and a greater convenience in making such changes as may be necessary during development. There is also no deposit of oxalate of lime when common water is used.

To realise the full benefit of the pyrogallic acid developer, each constituent should be kept separately. This method also has the advantage that if one of the chemicals deteriorates it does not involve the loss of another. But these observations do not apply when a considerable number of very similar negatives have to be developed, as often occurs in studio work.

The pyrogallic acid is conveniently kept in the solid condition, as its decomposition is then entirely prevented, and it is almost as easy to measure the solid substance as a solution of it. But if it is preferred to have the pyrogallic acid in solution, it may be dissolved in a convenient quantity of water, say to form a ten per cent. solution, and a little nitric acid or citric acid may be added to it, as little of the acid being used as is found to preserve the solution for the required time. It is well not to dissolve more pyrogallic acid than will serve for two or three days' use.

The precautions necessary in preparing, purchasing and dissolving sodium sulphite have been pointed out in the first part of this book. It is convenient to prepare a 50 per cent. solution of the crystallised salt, so that it is only necessary to take twice as many grain measures or cubic centimetres as there are grains or grammes required.

If an ounce of the salt is taken it must be so dissolved that the final bulk of solution is 1 oz. $6\frac{1}{2}$ drs. fluid measure, or the total bulk produced by dissolving 500 grammes should be 1000 c.c.

Bromide of potassium is to be preferred to bromide of ammonium, and a 10 per cent. solution is convenient. It may be observed that ammonium bromide, if used at all, must be restricted to those developers in which ammonia is the alkali employed. To prepare a 10 per cent. solution dissolve 1 oz. of the solid, making the total bulk of solution equal to 9 ozs. 1 dr. fluid measure, or prepare with 100 grammes a solution measuring 1000 c.c.

An alkali is also required. It is customary to use either ammonia, or sodium carbonate, or potassium carbonate, or a mixture of the last two. The two carbonates are conveniently taken in the crystalline form and dissolved to 10 per cent. solutions, taking the quantities as given for potassium bromide. The ammonia may be diluted to ten times its bulk, assuming that the strongest ammonia (s.g. .880) is at hand.

In studio portraiture, as often practised, development is no more an art than the fixing and varnishing of the plate; indeed, it is actually possible to apply always a uniform developer for a uniform time, and to secure what is wanted by suitable arrangements in the lighting, exposure, etc. But in landscape work it is wholly different. The range of light intensities varies in every view, and in every view it varies from hour to hour, and from day to day. The view cannot be regulated to suit the developer, therefore the development must be done to suit the view, and it is in this that the art of development lies. Even a rapid glance at published landscape photographs reveals the fact that a large proportion of them are only partially developed, and that in general the development has been done by rule-of-thumb.

The statement that a certain formula of development is that best suited to a certain make of plate is therefore only a guide to the nature of the plate. The process of development must be suited to the given subject taken on the plate employed. The chief use of a maker's formula

is to show the maximum amount of alkali and the minimum amounts of bromide and pyrogalllic acid, or, in other words, the most trying developer, that it is advisable to employ, or that the maker will guarantee his plate to bear; but these limitations will stand for little with the experienced operator.

As to the choice of alkali. Ammonia has many advantages. Its volatility and the mobility of its solution appear to give it exceptional energy, while at the same time its action is easily controlled. But it has one disadvantage—it is a solvent, though a very feeble one, of silver bromide, and this introduces a measure of uncertainty into its action. Gelatine is very liable to be stained by solutions of silver compounds. And it is a matter of fact that when bromide plates begin to deteriorate an ammonia developer will often produce silver stains upon them, while they work perfectly with other alkalies. In short, ammonia puts the quality and condition of the plate to a more severe test than sodium or potassium carbonate, and as there is always an element of uncertainty in its use, the author considers that the balance of advantage rests with the fixed alkalies. It has been stated that carbonate of potassium tends to give detail and carbonate of sodium density, but this depends very much on how each is used. On the whole sodium carbonate appears to be preferable to the potassium salt, and a mixture seems to offer no special advantage.

The sodium sulphite is used to ensure a clean working developer and a negative free from the coloured products that result when pyrogalllic acid in a simple alkaline solution is exposed to the air. It should be proportioned to the bulk of the developer rather than to the pyrogalllic acid contained in it. It will be well to increase it a little if the amount of alkali is increased to any notable degree, or if development is to be prolonged. When sodium carbonate is used, the amount of sulphite may be from 15 to 25 grains per ounce (or 30 to 50 grammes per 1000 c.c.) With ammonia less will suffice, namely, from six to eight grains per ounce (or 10 to 15 grammes per 1000 c.c.) There are some photographers who use ammonia and prefer to work

without any sulphite. They consider that they get a certain quality in the negative which is lost when sulphite is present. This idea is doubtless due to a want of experience in the use of sulphite. When this salt is absent there is always staining matter present in the negative due to the products of oxidation of the pyrogallic acid, and it appears very probable that the image consists partly of these dark-coloured substances and partly of metallic silver. Hence, probably, an inferior or poorly-coated plate will give a better negative when developed without sulphite because of this reinforcement of the silver image. But for certainty of results stains must be prevented, and the negative should have nothing in the gelatine film but the image in pure silver. The photographer then knows what he has, and if after-treatment of the negative is desirable he can proceed with confidence.

It has been already stated that a given formula is not suitable under all circumstances. But it is well to have a standard formula, suitable for what may be called average subjects, and it is convenient to regard the necessary modifications as variations of it. The formula that the author prefers is—

Pyrogallic acid	..	..	..	1 grain or	2 grammes.
Sodium sulphite	..	..	..	15 "	30 "
Potassium bromide	..	..	..	1 "	2 "
Sodium carbonate	..	..	..	1 "	2 "
Water to	..	..	..	1 ounce or	1,000 c.c.

The sulphite and carbonate are both crystallised, and a second or third proportion of carbonate or even more may be added as development proceeds.

If the solutions above recommended are employed, this developer will be made up as follows, multiplying every figure by the number of ounces of solution required, or proportionately adjusting the grammes and cubic centimetres.

Pyrogallic acid, solid..	..	..	1 grain	or	2 grammes.
Sodium sulphite, 50% sol..	..	..	30 minims	or	60 c.c.
Potassium bromide, 10% ..	..	..	10 "		20 "
Sodium carbonate, 10% ..	..	..	10 "		20 "
Water to	..	..	1 ounce or		1,000 "

adding more alkali as stated above.

This developer will work slowly. It may be four or five minutes before the image begins to appear, and 15 to 25 minutes before development is complete.

If ammonia is preferred, this may replace the sodium carbonate, using the same bulk of the ten per cent. diluted solution, reducing the sulphite to about one half.

In every case soak the plate in water first for a minute or two, taking care that no bubbles adhere to the film. Then pour off the water and apply the developer, and do not add the additional alkali so long as development proceeds satisfactorily. The high lights come out first, and as these grow in intensity the other detail appears. Experience alone will guide as to when to stop development, but it will generally be advisable to go on until the whole surface of the plate shows signs of darkening.

In this method of development the density of the negative grows with the detail, and it sometimes needs a little skill to prevent the high lights from getting too dense before the dark detail is out. If this accident happens, the negative is lost; subsequent reduction will not save it. It is possible that the negative may be improved by the accident, but an improvement got unwittingly, though good for the picture, is no credit to the operator—accidental improvements form no part of scientific development. The reduction of such a negative cannot be done with certainty without interfering with the gradation of opacity; unless, therefore, a change in the character of the negative is desired, if the high lights gain full density before all the detail is out the plate is lost beyond recall.

If by this method of development the high lights get too dense, give more exposure, reduce the pyrogalllic acid, reduce the bromide, increase the alkali, and make these changes in the order given until the desired effect is secured.

Plates that are known to be over-exposed may be soaked for a few minutes in the developer prepared with no alkali, adding this afterwards in small quantities at a time.

Plates that are under-exposed only to that extent that hardness is to be feared may be developed with those modifications given for avoiding hardness; but if the under-

exposure is considerable, as often occurs in the use of rapid shutters, it will be found at times impossible to get the desirable vigour by development only—the action stops as if the effect of the exposure was entirely exhausted. In such cases it appears to matter very little how the development is conducted so long as it is made as complete as possible, and intensification must be relied on for giving printing value.

Development may be carried out by getting the detail first and the density afterwards by applying a strong developer to begin with and until the plate is covered with detail, and then using a well-restrained developer. But this principle is not sound. In a plate exposed upon a subject that presents a considerable range of brightness there must be what is commonly called over-exposure or under-exposure or both, according to whether the exposure is suited to the darkest parts or the lightest parts of the subject, or those parts that present a medium luminosity. By putting a developer on the plate that is strong enough to bring out the darkest detail, the effect of the over-exposure is obtained in its full force, and consequently the high lights lose their gradation and their beauty. Where the range of brightness is only small this principle of development has its evil reduced to a perhaps negligible amount, and then the method may be useful.

A defective plate may require special precautions, but these are generally obvious. If the image shows vigorously through at the back of a gelatino-bromide plate before fixing, the coating is too thin or poor, and the plate not fit for use. As soon as any detail is developed right through the film its density ceases to increase, and the detail that was a little less luminous grows to an equal density, and the high lights lose their gradation and become flat. In any case development should be stopped as soon as any detail is right through on any part of the film; if all the detail is out, intensification may make a good negative of it, if not it is useless to spend any more time on it.

The most vital operation in the production of a good photograph is the development of the negative, and the development can with certainty be made perfect only when adequate skill is brought to bear upon a fully-exposed plate.

CHAPTER IV.

GELATINO-BROMIDE NEGATIVES. OTHER DEVELOPERS.

OF the reagents that may be used to replace pyrogallie acid in alkaline development, by far the most important is eikonogen, which was introduced in 1889 by M. Andresen. The principal advantages of eikonogen are that it allows (according to the experience of many photographers) a reduction in the exposure of perhaps one-fourth the time otherwise desirable, that it brings out with rapidity whatever can be developed upon a plate, and that it is specially convenient to use as a "one solution" developer. Of all the developers in use, it is most easy with eikonogen to avoid staining the gelatine; and there appear to be no developers except this one that will not, under aggravated circumstances, impart so permanent a stain to gelatine that neither water nor any allowable reagents will remove it.

Eikonogen is specially suitable for the development of hand-camera exposures, for studio work and other analogous cases. A solution may be conveniently prepared as follows, using hot water. And if the water is boiled for a few minutes, so as to drive out the dissolved air, it will be advantageous :

Crystallised sodium sulphite	..	50 grains or	100 grammes.
" sodium carbonate	..	50 "	100 "
Eikonogen	.. ..	25 "	50 "
Potassium bromide	.. ..	0.5 "	1 "
Water to	.. ..	1 ounce or	1,000 c.c.

For use this is diluted with an equal bulk of water for under-exposed plates, or with three or four times its bulk for fully-exposed plates. The bromide is distinctly advantageous in the small proportion given, though it has been stated to be unnecessary.

If ordinary landscape negatives are to be developed with eikonogen, the alkali would be better excluded from

the above formula. Plates may be treated with the eikonogen, sulphite and bromide alone, and if the exposure has been more than necessary, the image will probably develop satisfactorily without the addition of alkali. Eikonogen may thus be used after the manner recommended for pyrogallic acid, but it must be remembered that the bromide has a much greater retarding effect with eikonogen. The newer reagent can hardly be taken in the solid condition for each development, because of its sparing solubility; and to preserve it in solution sodium sulphite should be used, avoiding acids which decompose it. In these points it differs from pyrogallic acid.

Hydroquinone was first suggested as a developer in 1880 by Captain Abney. It may be used without a restrainer, as it has not so much vigour of action as either pyrogallic acid or eikonogen, and for the same reason it tends to give hard negatives, and is advantageously associated with caustic alkalies instead of carbonates. The formula first proposed by Captain Abney was twelve grains of hydroquinone with four drops of strong ammonia to one ounce of water. This he subsequently modified to from six to twelve grains of hydroquinone with one dram of a saturated solution of ammonium carbonate to one ounce of water. Since this a considerably less amount of hydroquinone has been stated to be effective.

A formula that has been much appreciated is due to Thomas & Co., and is as follows:—

Hydroquinone	..	..	4 grains or	8 grammes.
Sodium sulphite	..	..	22 "	44 "
Citric acid	..	..	1.5 "	3 "
Potassium bromide	..	..	1 "	2 "
Caustic soda	..	..	4 "	8 "
Water to	..	..	1 ounce or	1,000 c.c.

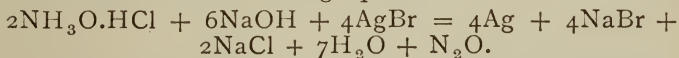
The caustic soda is kept separate from the other constituents. It may be dissolved in half of the water, which is kept apart for that purpose, mixing equal bulks of the two solutions for use. It is generally preferred to dilute this developer with at least an equal bulk of water.

The use of alkaline carbonates with hydroquinone leads to very uncertain results. The author has kept an

exposed plate under such a hydroquinone developer for half-an-hour, increasing the alkali very considerably towards the end of the time, without a trace of developing action being visible. This particular plate was then washed, and the developable image upon it was brought out with ease by means of pyrogallic acid. A part of the same sample of hydroquinone successfully developed another plate of a different kind.

In 1884, Carl Egli and Arnold Spiller suggested the hydrochlorate of hydroxylamine as a developer, claiming, as advantages, a wide latitude in exposure, and that the solution used is unaffected by the air, and therefore does not deteriorate by exposure. Gelatino-bromide plates yield with this developer a fine black image, quite free from stains, but the exposure must be rather more prolonged than for other developers.

Hydroxylamine is obtained by the reduction of nitric acid with tin and hydrochloric acid. It may be regarded as ammonia that has one of its hydrogen atoms replaced by the group OH, thus $\text{NH}_2(\text{OH})$. But as this compound cannot be obtained pure, its compound with hydrochloric acid, which crystallises with ease, is employed. Its formula is $\text{NH}_2\text{OH}.\text{HCl}$. A simple solution of this salt appears to be useless as a developer, and the addition of ammonia, or sodium carbonate, makes very little difference, but with caustic potash or caustic soda a solution can be prepared that will eventually, perhaps, get as much detail as an ordinary pyrogallic acid developer. The chemical changes that take place in the production of the image are probably those shown in the following equation:—



The nitrous oxide gas produced being liberated in the film tends to injure it by causing "reticulation," that is, a rough appearance due to innumerable little cracks. The caustic alkali is also troublesome from its softening the gelatine. A useful formula for this developer is—

Hydroxylamine hydrochlorate	..	2	grains	or	4	grammes.
Caustic soda	.. ..	3	"		6	"
Potassium bromide	.. ..	$\frac{1}{2}$	"		1	"
Water to	.. ..	1	ounce	or	1,000	c.c.

adding citric acid one grain (or two grammes) or less, if the water used is hard, to prevent the precipitation of lime carbonate (from the lime present in the water) upon the face of the negative. If the citric acid is necessary, the bromide of potassium may be omitted, except in cases of over-exposure. Hydroxylamine is stated to have a considerable tendency to cause frilling (and therefore must be used in dilute solutions), and to be unsuitable for developing plates that have received anything less than a full exposure.

Other developers have been proposed, and there are doubtless many substances that might be made serviceable, because the action of the developer is simply to rob the silver of its bromine. It is necessary, however, to arrange matters so that the reduction of the silver is so tardy that the effect of light upon the plate in facilitating the reduction shall be fully realised in all its gradation. A developer that cannot be made to fog a plate is not desirable, because a sensitive film that has been exposed in the camera or behind a negative is exposed all over more or less. A developer, therefore, that will not fog a plate is one that will not respond to the feeblest effects of the light, and so far tends to give a "hard" image. The "character of a wet plate negative" that is so much admired by some operators is desirable only on account of rapid printing—an important matter sometimes, but not so important as the perfection of gradation.

CHAPTER V.

GELATINO-BROMIDE NEGATIVES. FIXING, CLEARING, &c.

WHEN the developed negative is thoroughly washed it may be taken into ordinary light without fear of deterioration; but if it is not washed, the adhering developer may produce fog by causing reduction all over the plate, and if enough of the developing solution does not remain to produce fog, stains are likely to result. It is therefore better to fix the negative before it is taken out of the dark room.

The fixing of the negative consists in dissolving away completely the silver compound or compounds in the film, without injury to the image itself, which consists of very finely divided silver. If it were simply a matter of dissolving bromide of silver, potassium cyanide would be selected, for a comparatively dilute solution of this reagent works rapidly, and produces a double cyanide of potassium and silver which is easily washed out.

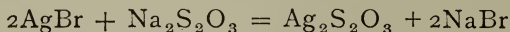


But potassium cyanide is not to be preferred because it dissolves to a slight extent the finely-divided silver that constitutes the image, and as it has a strong alkaline reaction it softens the gelatine.

Potassium bromide will combine with silver bromide, forming a double salt (KBr, AgBr), but this compound could not be washed out of the film with water, as water decomposes it into its constituents.

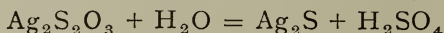
Sodium hyposulphite has advantages not possessed by any other known solvent of silver compounds. It attacks metallic silver so slowly that its action upon the image may be quite disregarded in the ordinary process of fixing. It has very little effect upon the gelatine itself, and the soluble compound that it forms when properly used is easily soluble

in water without decomposition. The sodium hyposulphite first changes the silver bromide into silver hyposulphite, thus—



and a further quantity of the sodium salt combines with the silver hyposulphite to form a double salt. There are two double hyposulphites of silver and sodium, $\text{Ag}_2\text{S}_2\text{O}_3$, $\text{Na}_2\text{S}_2\text{O}_3$ and $\text{Ag}_2\text{S}_2\text{O}_3, 2\text{Na}_2\text{S}_2\text{O}_3$. The first is practically insoluble in water, but the second is very soluble. For this reason it is necessary to have a large excess of the sodium salt.

The double salt itself, when gently warmed in solution, is decomposed, the hyposulphite of silver being changed into sulphide of silver, which is black and insoluble, thus—



But in the presence of excess of sodium hyposulphite this decomposition is scarcely possible.

The usual formula for the fixing bath is—

Sodium hyposulphite	..	..	4 ounces or	200 grammes.
Water to	..	..	1 pint or	1,000 c.c.

and this strength is specified merely because if much stronger the solution may not be able to penetrate the film so rapidly, and if much weaker it acts more slowly because its dissolving power is reduced.

It is preferable to dissolve the sodium hyposulphite at least a day before it is required, as this gives time for a slight turbidity that shows on first dissolving to settle down. The simple solution will keep a very long time without an appreciable loss of fixing power, but if an old solution is to be used it is well to test it for acidity, and add a little alkali if necessary.

There is advantage in adding a little sodium carbonate and sodium sulphite to the fixing bath, to prevent the possibility of the liberation of sulphur from it. The quantities are not very important, but the following will serve as an example :—

Sodium hyposulphite	..	..	4 ounces or	200 grammes.
Sodium carbonate	..	..	20 grains	„ 2 „
Sodium sulphite..	..	..	100 „	„ 10 „
Water to	..	..	1 pint	„ 1,000 c.c.

With this exception, nothing should be added to the hyposulphite of soda. Alum and acids decompose it with precipitation of sulphur and liberation of sulphurous anhydride, thus—



The sulphurous anhydride may have a cleaning action upon the film, but it is produced in this case at the expense of fixing power. Let the fixing bath do its own special work without interference, and give it plenty of time to act. A negative should not be considered fixed and ready for washing until it has remained in the fixing bath for about twice as long as was required before the visible milkiess of the film was removed. Fixing is not complete until an excess of hyposulphite of soda has reached every part of the film.

The amateur who works only occasionally should always take a fresh quantity of hyposulphite of sodium solution for every three or four negatives developed, and the professional would do well to have two fixing baths always in operation, and to give each negative fixed in the first a minute or two of soaking in the second. When the first bath shows signs of exhaustion by working slowly, it is rejected; the second bath now becomes the first, and a new second bath is taken into use.

An acid fixing bath has been much recommended of late, the idea being that the negative may be fixed and cleared at the same time, and the hyposulphite solution remain comparatively free from colour. To be sparing of hypo, or to use its solution until it can act no longer, is bad policy, because the salt is cheap, and the life of the negative depends upon its being thoroughly fixed. After alkaline development especially, an alkaline fixing bath is to be recommended, and by the proper use of sulphite in the developer, clearing will be rendered unnecessary.

Those, however, who desire to use an acid fixing bath will find it convenient to replace the carbonate and sulphite in the above formula by—

Sodium sulphite	..	..	$\frac{1}{2}$ ounce or 20 grammes.
Sulphuric acid..	..	..	20 minims or 2 c.c.

the acid after dilution to be added to a solution of the sulphite, and the mixed solution added to a solution of

the hyposulphite, the whole being then made up to the total bulk named.

If the negative has been developed, washed, and fixed as recommended, it will only need a thorough washing before it is put to dry. The washing may with advantage be extended to from one to three hours, according to the thickness of the film.

If the film shows a tendency to frill, that is, to separate from the glass at the edges of the plate, and if the frilling appears likely to extend to the image, the negative may be put into a saturated solution of alum for a few minutes after washing it as long as appears safe, the washing being continued after the treatment with alum.

A discolouration or stain upon the negative, produced by the darkened developer, shows a fault in the process of development. Sometimes such a stain is merely superficial, and may be removed by gently rubbing the film with a small pad of wet cotton wool. If this fails to remove the stain, the washing should be prolonged. By putting the plate in an acid solution the colour of the stain will sometimes be changed to a lighter tint, say from brown to yellow, but the staining material does not appear to be removed, as its deeper colour can be reproduced by means of an alkaline solution. The author has found that stains due to oxidised developers that were not removed by continued washing with water were quite unaffected by acids, and that, therefore, when a "clearing solution" lightens the colour of a stain, it shows that much of the stain would have been removed by continued washing.

The best way to get clear and stainless negatives is to keep them clear from the first by the judicious use of sulphite in the developer. But clearing solutions may occasionally be useful, and the following two formulæ are therefore appended:—

- | | | | | | |
|-----|-------------|----|----|----|--------------------------|
| (1) | Alum | .. | .. | .. | 2 ounces or 200 grammes. |
| | Citric acid | .. | .. | 1 | 100 " |
| | Water to.. | .. | .. | 10 | 1,000 c.c. |

- | | | | |
|-----|--------------------------------|----|--------------------|
| (2) | A saturated solution of alum.. | 1 | pint or 1,000 c.c. |
| | Hydrochloric acid | .. | ½ ounce or 25 c.c. |

Acids must be avoided after development with eikonogen. Stains due to this reagent are easily washed away with simple water.

CHAPTER VI.

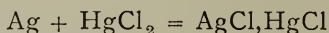
GELATINO-BROMIDE NEGATIVES. REDUCING.

WHEN a negative has been made too dense it needs reducing. If a plate has been under-exposed, and in attempting to force out the detail in the shadows the high lights have got too dense, reduction is also desirable. In the first case reduction is useful and possible, but in the second case it is not possible in a useful manner.

The image in a glass-supported gelatine film is on the outer surface of the film, and penetrates into the film in proportion to the opacity of the part. The reducing solution that is brought to bear upon the negative must begin its action at the outer surface of the film, and if it penetrates and acts completely as it goes, dissolving away the image, the dark detail will be rapidly thinned and probably altogether removed before the high lights are appreciably affected. A proportional reduction cannot with certainty be secured except by one or two unsatisfactory methods referred to below. In order to get as near to it as possible, the reducing solution must be dilute, that it may penetrate the film before it has time to do an appreciable amount of work.

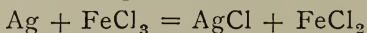
Most clearing solutions have a slight effect upon the image itself, reducing its density, particularly when no sulphite is used in development. Some photographers make a practice of putting every negative into hydrochloric or nitric acid, mixed with from five to ten times its bulk of water, to reduce the image slightly, and so give quicker printing qualities to the negative; but this needs special care lest the reduction should go too far, or the film should frill off the plate. In this case there is perhaps a proportional effect in every part of the negative. A not uncommon, though a not very wise, method which gives a

proportional reduction is to allow a saturated solution of mercuric chloride to act upon the film until it is bleached through, and then to wash it. The silver of the image is changed into a compound of chloride of silver and mercurous chloride, thus—



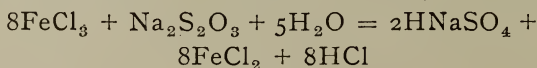
and although the amount of matter that composes the image is very considerably increased, the change of colour from black to white results in a diminution of opacity. This method is not wise because the results cannot be depended upon, for the bleached image will probably change by exposure in printing.

If reduction is necessary it is a better plan to dissolve away the image as far as is necessary. This is done by changing the silver of the image partially into chloride or bromide, and dissolving away this salt. There are many ways of changing the silver into its haloid salt, and there is little to choose between them. Ferric chloride, chloride of lime, hypochlorite of sodium, called eau de Javelle, or the corresponding potassium salt, either will, by the simple application of its dilute solution, effect the change. With ferric chloride, for example, we have



The chloride of silver is then to be dissolved away by refixing the plate, and the reduction is complete. The drawback to this method is that the extent of the reduction is determined by the first action, but is not visible until the hyposulphite of sodium has dissolved off the compound formed. What is wanted is that the acting and the dissolving ingredients shall be mixed, and thus that the reduction shall go on only as it proceeds visibly.

But this is a problem not so easily solved as would appear to one ignorant of the principles of chemistry, because the hyposulphite is easily oxidised by any of the reagents mentioned. With ferric chloride, for instance—



the ferric chloride is changed to ferrous chloride, and is

therefore robbed of its power to impart chlorine to the silver of the negative.

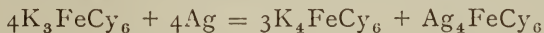
A method that combines in one solution the oxidiser (that is, the source of chlorine) and the solvent of the silver salt produced was suggested in 1883 by J. Spiller. He used a solution of cupric chloride mixed with a saturated solution of common salt. The cupric chloride gives chlorine to the silver—



and the common salt dissolves away the chlorides produced.

About the same time E. H. Farmer published a far neater method, and one that has met with considerable patronage. For the oxidiser he employs ferricyanide of potassium, because, while it is perfectly effective, it may be mixed in solution with sodium hyposulphite quite long enough for use before a very appreciable amount of reaction takes place between the two compounds.

The action of potassium ferricyanide upon the silver of the image is quite analogous to the action of ferric chloride given above, and in reality just as simple, though the chemical symbols appear more complex. Just as the FeCl_3 gives up a part of its chlorine and becomes $\text{FeCl}_2 + \text{Cl}$, so the K_3FeCy_6 gives up a part of its FeCy_6 to the silver—



and forms, according to this equation, the ferrocyanide of silver. It appears that some ferricyanide of silver is formed under certain conditions, though it is scarcely possible in this case in the presence of sodium hyposulphite. If the ferricyanide is produced it is by an analogous reaction—



and it matters nothing practically which silver compound is obtained, for either is no sooner produced than it dissolves in the sodium hyposulphite.

Though the precaution is not necessary, it is advisable to use a freshly prepared solution of potassium ferricyanide for this process, because this salt in solution is very easily decomposed by light or by contact with organic dust, &c. To reduce a negative, first soak it in water for a few

minutes, and replace the water with a 10 per cent. solution of sodium hyposulphite (2 oz. to the pint). While soaking in this put a crystal or two of the ferricyanide into a conical glass, and run water on and pour it off until the crystals are clean and of a bright ruby red. Add a little water, agitate for a few seconds, pour the solution so prepared into a glass, add the hyposulphite solution from the negative, and re-apply. Add more ferricyanide solution if the yellow colour of the mixed solution disappears, or if the reduction is too slow. After treatment, wash the negative as necessary after the usual fixing.

A purely physical method of reduction is often convenient, especially for local application. It is not safe to attempt to thin down the film by scraping it with a knife, or by rubbing it with a wet pad, but it is safe to use a pad moistened with alcohol. The film must be quite dry, and the pad may be a plug of cotton-wool, a piece of wash-leather, or silk, or other fabric, drawn over the finger-end or over a stick, or a piece of soft wood, such as an ordinary match, may be cut to a pointed or chisel-shaped end, and used without any covering when a line or a dot is to be rubbed away. The rubbing surface only needs moistening, as too much alcohol prevents the erosion, and it is easy to know whether any effect is being produced by the blackening of the rubber.

CHAPTER VII.

GELATINO-BROMIDE NEGATIVES. INTENSIFICATION.

IT will be gathered from the last chapter that reduction is an uncertain process, even in the hands of an expert, and is on the whole to be avoided. Intensification, on the other hand, is perhaps the simplest of photographic operations ; it may be performed by the tyro with certainty and success. Reduction always tends to alter the proportional opacity of different parts of the negative, but intensification never need do this, because it may be made complete, producing its change upon every particle of silver. Complete reduction would obviously be useless, as it would entirely remove the image.

Unless a special result is desired, and the operator is skilled enough to know how to produce it, intensification should be thorough—that is, each solution should produce its maximum effect and work right through the film. It is impossible to select a method that gives a sufficient increase in opacity to suit the most extreme need, and to make this a universal method, stopping its action in each case when it has gone far enough, because all solutions act first on the exposed surface of the film and gradually penetrate into it. If such a principle is adopted, a weak negative will be properly and proportionately strengthened, while a negative requiring only a little intensification will have its dark detail (say) doubled in opacity, because the solutions have acted thoroughly there, but the middle tones will have only (say) half their thickness and the high lights (say) a quarter of their thickness doubled by the process, because the solutions have not been allowed time to penetrate deeper. This result may be an improvement, and if secured of set purpose is sometimes very good ; but if the negative needs simple intensification it will be spoilt by this partial process, and if a procedure gives an improvement not sought for there

is neither science in the work nor skill in the operator. The function of science in photography is to give certainty.

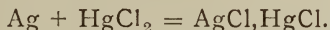
But if a partial intensification is to be condemned (except always in the hands of those who know the peculiarity of effect and when it is desirable), we must condemn in very much stronger language those processes of intensification in which the effect increases to a maximum and then diminishes by simply persevering with the original solution. Intensifiers that contain sodium hyposulphite or cyanide of potassium are liable to do this.

It is obvious that the result of intensification must be permanent, made neither darker nor lighter by daylight. As certainty of action and permanency of result are not only desirable but necessary to put a process of intensification on a proper scientific basis, all formulæ that contain a hyposulphite, a cyanide, or an iodide in conjunction with mercury, should be avoided. The mercury iodide and hyposulphite intensifier of Edwards, the mercury and silver cyanide process of Monkhoven, and other somewhat similar formulæ, have been proved by experience to be unreliable. There is no need ever to use processes such as these.

To prepare a plate for intensification it is always advisable and often necessary to destroy the small amount of hyposulphite that remains in the film from the fixing operation, to prevent staining. For this purpose the plate may be soaked for a few minutes in one of the clearing solutions mentioned in the last chapter, with subsequent washing. Or the plate may be soaked in a bath of hydrochloric acid diluted with about a hundred times its bulk of water, and intensification proceeded with without washing it.

Those methods of intensification that are most to be recommended result either in an addition to the silver of the image or an exchange of it for some other substance that is less transparent to photographically active light. This change is invariably effected by means of the reducing power of silver, using the word reduce in a chemical, and not in a photographic, sense. If a solution of corrosive sublimate (mercuric chloride) is allowed to act upon the

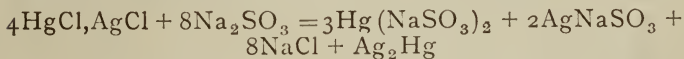
silver image it will be whitened, and at the same time considerably increased in bulk. The change is expressed thus—



To ensure cleanness in the result it is advisable to add one or two drops of strong hydrochloric acid to each ounce of the cold saturated solution of mercuric chloride (half a drachm may be added to 20 ounces, or 3 c.c. to 1,000 c.c.) No silver is removed from the image, but each atom of silver is changed into silver chloride, and associated with the silver chloride there is the mercurous chloride. Although there is a great increase of matter the image that results is less opaque because of its whiteness. To produce a practical intensification, therefore, it is necessary to change the colour of the image. There are many reagents that will effect this, though very few are to be recommended without qualification.

Ammonia may be used in a dilute solution, and gives a fine black image. The strength of ammonia used is conveniently from ten to twenty drops to the ounce, or from two to four per cent., and it must not be applied until the negative has been thoroughly washed. This is a method that has met with much favour.

A useful process is to follow the mercury solution, after washing which need not be prolonged, with a solution of sodium sulphite. This reagent dissolves away three-fourths of the mercury and half the silver, leaving the rest of the metals in the metallic state to form the image.



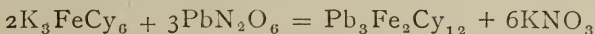
The intensification is not so great in this case as when ammonia is used; indeed, it is often very slight. The sodium sulphite solution is conveniently of from five to ten per cent. strength and slightly acidulated, and this, like the mercury solution, may be used repeatedly until it ceases to act quickly enough. The sodium sulphite has no effect upon mercuric chloride, and the only result of too little washing between the application of the two solutions is a retardation of the action of the sulphite.

If the mercuric chloride is followed by ferrous oxalate, both the metals of the mercurous silver chloride are reduced to the metallic state. The result, therefore, is that each atom of silver in the original image has by the process got associated with it an atom of mercury. This method gives a greater increase of opacity than the sulphite of soda, but perhaps the chief advantage is that the process of intensification may be repeated any number of times. The ferrous oxalate solution is conveniently prepared by pouring one volume of a saturated solution of ferrous sulphate into six volumes of a saturated solution of potassium oxalate, slightly acidified with oxalic acid. The solution may be diluted, but then it will act more slowly.

Including only those methods of intensification that are, so far as is known, reliable, there is only one other general process besides that involving the use of mercuric chloride. This second process involves the use of certain ferricyanides. It may be considered that the silver of the image reduces ferricyanides to ferrocyanides, itself becoming at the same time either a ferro- or ferricyanide, as shown in the chapter on the reduction of negatives. If the ferricyanide of a metal that forms a soluble ferricyanide and an insoluble ferrocyanide is selected, and its solution is caused to act upon the silver image, the silver is changed into its ferro- or ferricyanide, and is associated with the ferrocyanide of the metal chosen. The reaction is somewhat analogous to that of mercuric chloride, and gives the salts of two metals instead of the single metal itself. If uranium ferricyanide is used, the reddish or chocolate-coloured salts of the silver and uranium that result are so opaque to photographically useful light, that no further change is necessary. When lead ferricyanide is used, the resulting image is practically white, and needs to be treated with ammonium sulphide or potassium chromate. The first changes the silver and lead into their sulphides, which are black, and the second into their chromates, which are red and yellow respectively.

As it is not convenient to prepare the ferricyanides of such metals as uranium and lead, it is usual to employ a

mixture of potassium ferricyanide and the nitrate of the metal. The ferricyanide of the metal is then produced, as, for example, with lead—



and the potassium nitrate, which is also produced, does not interfere with the reaction. There are many precautions necessary with these methods. In the first case, as it is essential that the ferrocyanide of the metal employed should be insoluble, the introduction of ferrocyanides into the solution by any means other than by the action of the silver image itself must be rigorously avoided. The crystals of potassium ferricyanide are often coated with a layer of ferrocyanide produced by the action of light, of dust, or possibly a gas in the air like sulphuretted hydrogen which has a reducing action. The crystals should therefore be washed by running water over them for a few seconds until they are quite clean and of a bright ruby red colour, before they are dissolved, unless the mixed solution is to be prepared some time beforehand. In the latter case the ferrocyanide of the metal is precipitated in the solution, and filtration immediately before use will remove it. The process of intensification should not be carried out immediately under a window that is strongly illuminated, as sunlight decomposes the ferricyanide. It is best to use distilled water, but tap water should be preferred to rain water, and if it is hard it should be acidulated with acetic acid, as hard water reduces the intensity of the uranium image. Indeed, in any case, the uranium solution should be acidified. Acetic acid may be added to the extent of about $\frac{1}{50}$ th of the bulk of solution, or even to a rather greater proportion. If hard water were used with the lead process the carbonates and sulphates in it would precipitate carbonate and sulphate of lead upon the negative, and these salts would be blackened by the ammonium sulphide and cause fog. The addition of a little acetic acid to the lead solution will be found beneficial.

The following formulæ are recommended for these two intensifiers:—

Uranium Intensifier.—Uranium nitrate, four grains to

one ounce of water, or 10 grammes to 1,000 c.c., and with acetic acid as stated above. After soaking the plate in this, mix the liquid with a dilute solution of potassium ferricyanide made by running water over a few crystals to wash them, and then shaking them with a little water for a few seconds. Add more ferricyanide as necessary. The washing after this intensifier must not be prolonged or the image will lose density.

The Lead Intensifier.—

Lead nitrate .. ..	.. 20 grains or	40 grammes.
Potassium ferricyanide ..	30 ..	60 ..
Acetic acid .. ..	.. 10 minims or	20 c.c.
Water to .. ..	.. 1 ounce or	1,000 c.c.

When the image is bleached, follow, after a very thorough washing, with ammonium sulphide diluted with ten times its bulk of water. The washing before the ammonium sulphide is applied should be continued until the drainings from the plate give a scarcely perceptible blue colour with ferrous sulphate solution, that is, until the ferricyanide is quite washed out, for the least trace of lead remaining will inevitably cause fog.

By the adaptation of the methods described it is possible to formulate a system of intensification whereby a strengthening of the negative to any useful degree may be obtained with fair certainty. In the following series of operations each change is supposed to be thorough, that is, that the change of colour in every case is visibly complete at the back of the plate in the densest part of the negative.

1. Mercuric chloride, followed, after washing, with sodium sulphite, gives the little addition of brilliancy sometimes wanted in a carefully made and successful negative.

2. Mercuric chloride on the original negative, followed, after thorough washing, by ferrous oxalate, gives about as much increase of density as compared with number 1, as number 1 gives when compared with the original negative.

3. A repetition of the application of mercuric chloride and ferrous oxalate—that is, these reagents applied to the result of number 2—gives another step in the intensification.

(Note.—*The result of this treatment is about equal to the action of mercuric chloride followed by ammonia upon the original negative.*)

4. The result of number 3 may be treated again with mercuric chloride and ferrous oxalate, and so on as may be necessary.

5. The fourth or fifth consecutive application of mercuric chloride and ferrous oxalate will probably give a result about equal to that of the uranium intensifier acting upon the original negative.

6. If a still greater effect is desired, the lead intensifier may be used on the original negative.

The last method is practically useless in the treatment of half-tone negatives, because the result is so very great; and the uranium formula is only needed when the negative has a mere ghost of an image upon it. It may be noted that the uranium intensifier is as effective on the images resulting from intensification with mercury and sulphite, or mercury and ferrous oxalate, as upon the original negative.

Those operators who are accustomed to use the mercury and ammonia method, and find that it is sometimes too vigorous, can retain the use of this intensifier when required; but for milder effects, use the first or second method described, and so have three grades of intensification, each needing two solutions only. But those who prefer a result that they can confidently regard as permanent may reject the mercury and ammonia altogether, and get about an equal result, and one that is as amenable to intensification as the original, by adopting the methods given above.

It is possible to intensify gelatine negatives by causing a deposit of silver upon the silver image in the manner customary with wet-collodion negatives (which see), but this is not advisable, because nitrate of silver so readily stains gelatine. But, if this staining is quite obviated, as it probably may be, silver intensification is not desirable, because it can hardly be so definite and certain as those processes whereby an exact substitution is effected. Some photographers have tried to formulate processes of intensi-

fication before fixing; but such methods would be of very limited use, because the opacity of the unfixed film would remain as effectual a barrier against a correct judgment of density as during development.

It is sometimes desirable to reduce an intensified plate. A dilute solution of potassium cyanide, made by adding a drop or two of a moderately strong solution to three or four ounces or 100 c.c. of water, will reduce after the mercury and sulphite, or the mercury and ferrous oxalate. A similarly dilute solution of ammonium carbonate will be effective after the uranium process, or, instead, the washing may be prolonged.

CHAPTER VIII.

GELATINO-BROMIDE NEGATIVES. VARNISHING.

A NEGATIVE can be printed from without varnishing it, and probably little danger will result if strict care is taken to dry both the negative and sensitive paper by warming them a minute or two before placing them in contact. But to print from the unprotected film is always risky if ordinary silver paper is employed, as the smallest amount of silver nitrate that gets transferred to the gelatine film is almost certain to cause red stains sooner or later.*

It is a good practice to rub the surface of the negative with cotton-wool or soft rag moistened with alcohol before proceeding to varnish it, as by this means any surface contamination is likely to get removed, the flow of the varnish over the plate is greatly facilitated, and the film receives a polish that contributes to the smoothness of the varnished surface. The rubbing may be continued until the polishing is effected, if only an inappreciable blackening of the rubber takes place, but it should be remembered that this blackening is due to the removal of a part of the image. After this treatment, the negative should be warmed before a fire until the glass side is rather hotter than the back of the hand can bear to thoroughly dry the film. When the plate has cooled to a temperature that is comfortably warm to the back of the hand, it is brushed over lightly with a wide camel-hair brush, and a pool of varnish is poured into the middle of the plate slowly and steadily until it covers about half its surface. The plate is then

* Such red stains may be removed by the careful application of a dilute solution of potassium cyanide, if they are not too old, but potassium cyanide will also dissolve away the image if it has the opportunity.

tipped a little to cause the varnish to flow into each corner in turn, and the excess of varnish is poured off from the last corner, while the negative is "rocked" or moved to and fro in such a manner that the flow of varnish does not produce streaks. The plate is then moved about in front of the fire until it is about as hot as it was made at first. To avoid a thick streak of varnish along the two sides of the plate that meet at the pouring off corner, it is advisable to remove the excess as soon as the draining is finished by drawing a cloth tightly over the finger and passing it along these two edges, so as only just to touch the extreme edge of the glass.

A good varnish that is not too thin, applied in this manner, affords a reasonable amount of protection, but if the negative were put into water, probably in ten minutes or so the water would have penetrated the varnish where it is thinnest, that is, opposite the corner at which the excess was poured off.

A valuable negative should be coated with collodion before it is varnished. First warm it, to thoroughly dry the gelatine film, and as soon as it is cold coat it with a good enamel collodion. Then warm it to the required temperature and varnish it as above. If the varnish is poured off at the corner opposite to that at which the collodion is poured off, the combined films of collodion and varnish will be of more equal thickness throughout, as the thinnest part of one will be opposite the thickest part of the other.

The two chief gums employed in the manufacture of varnishes for photographic purposes are lac and sandarac. Lac is harder than sandarac, and to be preferred on that account; but it is of a deep red colour, while sandarac is practically colourless. A varnish made of lac, however, can readily be decolourised by means of animal charcoal to such an extent that the film yielded by it shows practically no colour. Lac is found in commerce in a bleached, and a nearly bleached, condition (shellac); but these preparations are to be avoided, because it is very difficult to get rid of the last traces of acid used in the bleaching process. Seed-lac is to be preferred to stick-lac, because

it has less colour, but this amount of decolouration is effected only by means of water.

“White hard varnish” of commerce is stated to be simply a solution of sandarac in alcohol, while “brown hard varnish” is made of a mixture of two parts of shellac to three parts of sandarac. Either of these thinned down with methylated spirit will give a varnish that may be used for negatives, though, obviously, the preparation will not be so reliable as if the history of the varnish were exactly known.

A formula for negative varnish recommended by W. Bedford is—

Button lac	..	..	..	..	..	8 ounces
Sandarac	..	..	..	..	..	2 „
Methylated spirit	..	..	..	..	..	2 quarts

shake at intervals for a week and filter. This is intended to follow collodion, but may be used without.

A varnish that can scarcely be excelled is prepared by putting seed-lac into methylated spirit, and shaking them together at intervals during three or four days. The amount of alcohol may be three or four times as much as suffices to cover the lac—the amount is not important. When the extraction appears complete, the mixture is allowed to settle for a day, and the solution is poured off. To decolourise it, animal charcoal is added to it, and the vessel containing it is heated in hot water for, perhaps, an hour. The solution is then filtered, and diluted with methylated spirit, until of a suitable strength, as shown by coating a plate with it. The extraction with alcohol should be done cold, as the waxy constituent of the lac is then not dissolved out.

If a varnish of the nature of those just described gives a film that is too brittle, castor oil may be added to it in any quantity up to one dram to the quart of varnish. Castor oil is preferred to other oils, because it neither hardens nor evaporates by exposure.

Amber may be dissolved to form a varnish by heating it until it begins to soften, then powdering it and agitating it with chloroform, or benzene, in the proportion of about one ounce of solid to sixteen ounces of liquid. Such a

varnish is applied to the cold plate. Amber varnishes are not to be recommended, as they are very troublesome to remove, and thus, perhaps, prevent a desirable improvement in the negative from being carried out.

Alcohol varnishes are readily removed by soaking the negative in alcohol, with a gentle rubbing to facilitate the solution of the thicker parts of the film.

CHAPTER IX.

GELATINO-BROMIDE NEGATIVES. SOLARISATION AND HALATION.

IF a uniform developer is employed, it will be found that an increase of light acting upon a sensitive plate will give an increase in the opacity of the deposit produced up to a certain point, that a further increase of light is then without apparent effect, and that, as the intensity of light or the time of its action increases, the opacity produced on development will diminish to practically nothing, and then increase a second time, and so on. For want of a better term, this effect is called "solarisation."

The reversal of the photographic image by reason of over-exposure is a phenomenon that is not duly appreciated by negative makers in general. Janssen found in photographing the sun, that from one to two hundred thousand times the most convenient exposure gave a positive instead of a negative on development, and that if the exposure were increased to a million times, a second reversal took place and a negative was produced. By further exposure, the phenomena could be repeated, but the images grew weaker each time.

But with a very much less excess of exposure, the effect of reversal begins to show itself injuriously, and this especially with gelatine plates. A pure bromide of silver emulsion (that is, free from iodide of silver) is most liable to suffer in this way. Bennett showed that with his plates double the exposure that gave full density caused a very marked diminution of density, and that ten times the exposure was equivalent on development to no exposure at all.

The brightest parts of the high lights are the first to begin to reverse—that is, they are thinner in the nega-

tive than they ought to be; and this gives flatness and hardness where there ought to be brilliancy and transparency—a fault that some operators are inclined to consider as inherent in the photographic process. We know that exposure and development are in a degree reciprocal, hence reversal is largely a matter of development. A powerful developer will give flatness in the lights, when a weak developer would have given a pleasing gradation that would not have been lost on strengthening the developer to get the dark detail.

Practical use of the reversal of the image by prolonged exposure was made long since in getting a negative directly from a negative; but, probably, the best method of applying this principle is according to the following process, devised by T. Bolas:—A gelatino-bromide plate is soaked for a few minutes in a four per cent. solution of potassium dichromate, rinsed with fifty per cent. alcohol, dried, and exposed under the negative to be reproduced for from two to five minutes in sunshine, or from ten to fifteen minutes in good diffused daylight. The plate is then washed in cold water, and developed with an alkaline pyrogalllic acid developer. The action of the chromate is probably two-fold—it hardens the gelatine, and so retards development in proportion as the light has gained access to the plate; and as reversal will not take place except in the presence of either the oxygen of the air or available oxygen from some other source, it may be that the chromate, which is a very powerful oxidiser, assists directly in the solarisation.

Colonel J. Waterhouse has quite recently (1890) found that reversal may be brought about without prolonging exposure by adding to an eikonogen developer an exceedingly small quantity of thiosinamine. He has since found that thiocarbamide is preferable, especially when lithium carbonate is used as the alkali. Reversal by means of these reagents is only in the experimental stage at present, but the important point to observe is that the modified development produces the same effect as a very prolonged exposure.

Halation is another result of over-exposure, but indirectly. The word in its broadest and most commonly

accepted sense indicates the spreading of light beyond its proper boundaries in the image with the production of the local fog that is especially to be observed round high lights, such as windows facing the sky in interiors. Halation is certainly present in negatives produced of very many less difficult subjects. Tree branches that stand out in front of the sky are often fogged in the negative, and the fine detail is quite lost so far as printing value is concerned, because the spreading of the light takes place from both sides. Loss of such fine detail, however, may result from other causes, such as movement of the object or of the camera during the exposure, or because of the lost detail not being in sharp focus.

There are two or three reasons why the light should encroach upon the shadow in negatives, but the chief is because of the reflection from the back surface of the glass. When light impinges upon the solid particles of silver salt in a gelatine film, it is impeded by them, and reflected by them in practically all directions. It is partly reflected sideways, and so affects the silver salt beyond the limit to which it is desirable to confine the light action. But the spreading of the light effect by this direct reflection from the particles may be neglected, except, perhaps, when fine lines have to be reproduced, because the number of particles soon absorbs, uses up, or exhausts the reflected light. But when the sensitive film is thin enough to allow light to pass through it, it appears that a considerable amount is transmitted in all directions from the back of the film into the glass, so that the film behind a luminous part of the negative may be considered, for all practical purposes, as an actual source of light. The light that radiates from this impinges chiefly upon the back surface of the glass, and here a part is transmitted out of the glass and is lost, but a part is reflected back through the glass again, on to the

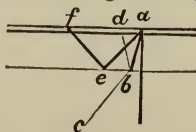


FIG. 45.

sensitive film, and produces the annoying local fog now under discussion. In figure 45, *a* represents a bright part of a negative from which the light is scattered in all directions into the glass support of the negative below. A pencil of light that passes through the glass plate at right angles to its surfaces passes out of the glass and does no damage, but a pencil that impinges upon the lower surface of the glass more or less obliquely, as *a, b*, passes partly out of the glass to *c*, and is partially reflected to *d* upon the underside of the sensitive film. As the obliquity of the pencils of light within the glass increases, the proportion that is reflected increases until, when the angle that the pencil makes with the perpendicular is equal to about 40 degrees (this figure varies according to the refractive index of the glass), the whole of the light is reflected. The effect of this is to surround a bright line with a fog that gets denser to a position a little distance away from the bright line itself, and then gradually fades away. The halation in this case produces a halo, and the distance of the halo from the bright line is greater or less according to the thickness of the glass.

But, if instead of a bright line we have a bright surface, the interval between the bright part and the halo disappears, and only a general fog remains that dies away gradually at a little distance. It is obvious in this case that the edge of the bright part produces an effect as described above, but the parts just within the edge produce the same result, and so the space between the edge of the bright part and its halo is filled up.

The proper way of curing this, the chief form of halation, is to use a film so richly charged with silver salt that it absorbs all the photographically active light that falls upon it. For landscape work plates ought to be coated thickly enough to entirely overcome this difficulty, even when a dark foliage foreground and a bright sky are taken upon the same plate. There are commercial plates that do this. A far inferior method is to colour the film with a red or yellow dye of such a nature that it is easily removed after or during development. Many of the coal tar dyes are of this character, and the effect of a tinted film in curing halation may sometimes be seen in using orthochromatic plates.

In those cases where the subject is of such a character that it is impracticable to absorb in the film all the light that falls upon it from the most luminous part—as, for example, a bright sky seen through a window in photographing an interior—and if it is impossible to modify the subject by reducing the brightness of the troublesome part, halation may be mitigated by “backing” the glass, so as to reduce or modify the reflection. A suitable material for this purpose may be black or else brown, red or yellow, as light reflected from such colours is very feeble in photographic effect. The mixture must be easily cleaned off before development, and must not be of so moist a character that it endangers the keeping properties of the film.

Many methods of backing sensitive plates have been proposed. A thin solution of bitumen in benzene (or Bates’s black varnish, or Brunswick or Berlin black) may be applied with a brush; it dries almost as quickly as it is put on, and is easily removed by rubbing with a little cotton-wool moistened with benzene or turpentine.

An aqueous mixture quoted by Captain Abney is as follows:—

Powdered burnt sienna	..	..	..	1 ounce.
Gum	..	..	..	1 ounce.
Glycerine	..	..	..	2 drachms.
Water	..	..	..	10 ounces.

This dries in a minute or two, and is wiped off before development with a damp cloth or its equivalent.

Black glazed paper or American cloth may be pressed into optical contact with the back of the plate after smearing a little glycerine over it; or a piece of carbon tissue may be applied in the same way. If the tissue is too horny, put it in a damp place for a few hours, but the more flexible materials mentioned above are to be preferred. Carbon tissue thoroughly soaked in water is easily put on, and is effective, but the large quantity of water is a drawback if the plate is not for immediate use. Mr. W. E. Debenham has shown that a mixture of caramel and gelatine is superior to any of these.

For a plate backing to be thoroughly effective it must

have the same refractive index as the glass and be in optical contact with it, so that light in passing from the one medium to the other suffers no refraction, for if there is refraction there must be reflection. The backing must form, in fact, an actual continuation of the glass, and vary from it, so far as it affects light, only in its opacity. It should preferably contain no opaque particles, but allow the light to travel in it until it is absorbed.

But when the halation by reflection from the glass is entirely prevented by mounting the sensitive film upon an opaque support, the fogging around high lights is still perceptible. The chief cause of this is probably to be found in the motes which we see very markedly when a beam of bright light passes through the air. The visibility of these motes is proof that they reflect light. Under ordinary circumstances the path of every pencil of light that passes from the lens to the sensitive surface is in a measure luminous, and scatters light in every direction within the camera. The effect of this scattered light is to produce fog upon the plate round the proper image of the luminous object, and a fog that gradually decreases in density from the image of the light outwards, and may extend an inch or two before it fades away. It is not practically possible to cure this defect, and, indeed, it is not worth while to spend much trouble about it, as it is not obtrusive in even difficult subjects.

And the lens itself is a source of scattered light, for the very best of lenses are not polished to such perfection as is necessary in a good telescope objective of large size, because such refinement would add to the expense, without giving any appreciable improvement—at least, in the vast majority of cases—in its performance in the camera. The imperfections of finish in a photographic lens are easily seen by holding the instrument between the eye and a candle or gas flame, and moving the lens to one side, so that the flame just disappears. The lens will now appear luminous, showing that the irregularities of its surfaces are sufficiently numerous and great to reflect the light in stray directions in a manner similar to the motes in the sunbeam. The tendency of this imperfection of the lens

is, probably, to give a uniform fog over the whole plate, rather than the local fog that is more immediately under discussion.

It is worth stating here that, in 1863, J. H. Dallmeyer had an order from J. W. Osborne, for the Melbourne Government, to construct a photographic objective in which the lens surfaces were to be as perfectly finished as in the best large objectives of astronomical telescopes, and that the price agreed upon was £250, probably more than ten times the cost of the same lens as usually finished. The lens was for the copying of maps for reproduction by photo-lithography ; but the author does not know whether the instrument gave results which justified its large cost.

CHAPTER X.

GELATINO-BROMIDE FILM NEGATIVES.

THE earliest negatives, by Herschel and by Talbot, were made upon paper, and it was a very considerable advance when glass was employed. The paper negatives, however, had so many advantages that the process was not discarded, and for the last sixteen or seventeen years much labour has been devoted to the production of film-supported negatives that shall not have the drawbacks commonly associated with them.

The advantages of film negatives are the lightness of the material and often the possibility of using it in long lengths in roller slides, the absence of reflection from the back surface of a supporting medium, and the possibility of printing from either side. An emulsion spread on an opaque support, such as paper, appears to be much more sensitive than if on a transparent support.

On the other hand, a film negative very rarely prints as quickly as a glass-supported negative. It is difficult to get so even and perfect a coating of emulsion upon it; its surface is very rarely so true as that of a sheet of glass however the film may be held in the camera, and there is always extra manipulation needed in making the negative. It is more difficult to varnish or otherwise sufficiently protect the surfaces of a film negative.

It must not be understood that all film negatives have the advantages or the disadvantages just enumerated. A glass negative may be printed from the reverse way—that is, with the film towards the light instead of towards the sensitive paper, but the amount of blurring would almost obliterate the subject. There are probably no commercial negative tissues that will allow of printing from their reverse sides without a loss of detail that is fatal to a small picture.

In 1875, Warnerke worked out a process of manufacturing a dry collodion paper-supported film, which could be exposed in roller slides, and was preferably stripped from its support before development. He shortly after supplied such films in blocks, so that each one as it was exposed was removed to leave the film below ready for exposure. From time to time other workers have also tried to produce satisfactory thin, flexible and transparent supports for negative films. H. J. Palmer coated gelatine films with gelatine emulsion, but as he prepared the sheets on glass the size was limited and the cost considerable. Moreover, simple gelatine as a support has several drawbacks. It varies according to the amount of moisture present in the air, and when thoroughly dry it is too brittle.

The first negative tissue that can claim any degree of popularity was that prepared by the Eastman Dry Plate and Film Company in 1885. In this process the gelatine emulsion is supported on paper, but not directly, because the unevenness of the surface of paper would cause a similar irregularity in the side of the emulsion film in contact with it, and so give an objectionable granularity in the negative. The paper of the Eastman Company was first coated with gelatine, and then calendered to obtain a polished surface to receive the sensitive emulsion. To secure an even coating, the sensitive emulsion was put on in two layers. The development of this tissue offered no special difficulties, and to get flatness in the finished negative, it was taken from the last wash-water, and squeegeed down upon a sheet of polished ebonite. When dry it was readily stripped from the ebonite.

Though such negatives could be printed from without further preparation, it was customary to make them more transparent. The first method suggested was to immerse them in hot castor oil; then cold oil was applied, allowing it several hours to soak in; and finally vaseline was used for the purpose. This process imparts an excellent quality to the negative, but the oil gradually works out, and always offers an effectual trap to dust.

To overcome these difficulties, the Eastman Company in 1887 prepared a stripping film, which differed from the

other chiefly in having a layer of soluble gelatine between the emulsion film and its support. After fixing and washing for a short time, the developed negative was squeegeed down upon a glass plate coated with collodion, and, after a few minutes, hot water was poured over it to melt the layer of soluble gelatine, and so allow the paper to be peeled off. A gelatine skin was squeegeed on, and when dry, the finished negative was stripped from the glass. The negative thus had a coating of collodion on its face. To ensure the collodion leaving the glass in such an operation the surface of the plate must be either dusted with French chalk, or, preferably, coated with a thin film of indiarubber by means of a solution in benzene of the strength of about half a grain to the ounce. To secure flexibility in the finished negative, the gelatine skin applied to give it the needed strength was prepared with a certain proportion of glycerine, and care had to be taken that the glycerine was not soaked out of it.

Instead of getting rid of the granularity caused by coating paper directly with a sensitive emulsion, by preparing the surface of the paper, the support may be coated on both sides with the sensitive compound. Such a film has the advantage that either side may be exposed, but this is a very trivial matter. The use of the second coat is to correct irregularities in the first, and this it does satisfactorily, because, where the front film is thin, more light passes through to the back film, and the thinness is compensated for. Such a tissue was made by the Vergara Company (working on the suggestions of W. B. Woodbury) in 1886, the foundation being a thin paper made transparent with a benzene varnish. It was found practically impossible, however, to get a satisfactory coating on both sides simultaneously, and this preparation was replaced in 1887 by a tough material coated on one side only patented by Froedman.

Other films for negatives have been made commercially, among which may be mentioned Pumphrey's, Balagny's, and Thiebault's. The last were on enamelled cardboard, and used exactly as glass plates, except that in developing the density of the image had to be judged of from the

surface appearance only. When finished they were removed from the supporting cards. They were very expensive. Balagny's support was "composed of a succession of very adhesive films of collodion, varnish, and gelatine."

As a film support in negatives, celluloid has, practically speaking, replaced everything else. Celluloid is a transparent preparation of pyroxyline and camphor, and with various pigments incorporated with it has been in use for many years in the manufacture of small articles. In 1888, John Carbutt, of Philadelphia, succeeded in obtaining this material in a fit condition for coating with emulsion, and since then many manufacturers have followed his example. In 1890, the Eastman Company succeeded in preparing a celluloid film of sufficient thinness for use in roller slides.

To bring to a conclusion these observations concerning the methods now generally in vogue for producing negatives, it cannot be too vividly and persistently remembered by the photographer that a negative is only a means to an end, and has no beauty, except inasmuch as it is able to furnish beautiful prints. To value a negative simply for its own sake is altogether unreasonable; and to call a negative good when it gives only an inferior print is equivalent to praising an ornamental but a useless tool.

CHAPTER XI.

COLLODION. ITS MANUFACTURE.

PYROXYLINE is a nitrate of cellulose, and cellulose is the essential constituent of purified vegetable fibre, such as cotton, unsized paper, etc. Collodion is a solution of pyroxy line in a mixture of alcohol and ether.

Just as nitrate of sodium results when nitric acid acts upon caustic soda, so nitrate of cellulose is obtained by the action of nitric acid upon cellulose. But in this latter case it is possible to produce several nitrates according to the extent of the action of the acid, and, therefore, if an approximately definite preparation is desired, it is necessary to control the reaction. Sulphuric acid is invariably mixed with the nitric acid, as it affords a valuable means of regulating the reaction, on account of its eagerly combining with the water which is produced. The sulphuric acid is necessary also to prevent the loss of the cotton by its solution in the nitric acid, and it has probably another effect analogous to the toughening it produces in the making of parchment paper. By the further action of the somewhat diluted sulphuric acid, cellulose is changed into a dextrine or sugary product. Concentrated nitric acid has a very remarkable toughening effect upon paper that is immersed in it for a few seconds and is then washed.

The changes, therefore, that cotton undergoes when subjected to the action of the mixture of acids may be very complex, and not to be simply described as the formation of a nitrate, though this is the only change that can be definitely expressed.

When the strongest acids are used at a low temperature (50° Fahr.), and the action is prolonged for twenty-four

hours or so, a cellulose trinitrate ($C_6H_7(NO_2)_3O_5$) is produced, which is insoluble in a mixture of alcohol and ether, and is more violently explosive than any other cellulose nitrate. It is the gun cotton of warfare. By using diluted acids at a higher temperature (130° to 150° Fahr.), and stopping the action after about ten minutes or rather more, the chief product is a dinitrate ($C_6H_8(NO_2)_2O_5$), which is readily soluble in a mixture of alcohol and ether, and is the essential constituent of pyroxyline. By the action of hot dilute nitric acid a mono-nitrate ($C_6H_9(NO_2)O_5$) may be prepared, which is readily soluble; and it is stated that there are intermediate nitrates between the three just mentioned, which require more complicated formulæ for their expression.

Potassium nitrate may be used instead of nitric acid if more sulphuric acid is added to liberate the nitric acid from it, and the salt has the advantage over the acid of being easily obtained pure, and not being liable to decomposition by storage.

The following two formulæ will give an idea of the suitable proportions:—

Sulphuric acid, S.G. 1.845	..	18	fluid ounces.	
Nitric acid, S.G. 1.45	..	6½	„	
Water	.. ..	4¼	„	(Abney).
Potassium nitrate, dry	..	510	grains	
Sulphuric acid	.. ..	15½	drachms.	
Water	.. ..	1½	„	(Hardwich).

As soon as the cotton is withdrawn from the acids, it should be thoroughly washed, as it seems probable that a small quantity of acid remaining in it tends to produce a subsequent decomposition. If thoroughly washed and dried, the pyroxyline may be stored without fear of spontaneous change.

To make collodion, the pyroxyline is dissolved in a mixture of ether and alcohol (it is not soluble in either separately) in the proportion of about six grains to the measured ounce of solvents, or 12 to 13 grammes to 1,000 c.c., but more or less pyroxyline may be taken according to circumstances. It depends upon the purpose to which the collodion is to be applied whether the solvents must be

pure, and in what proportion they should be used. If an "enamel collodion" is desired—that is, a collodion to be used simply to give a protective film to prints or to negatives—methylated alcohol and methylated ether may be used according to the following formula—

Pyroxyline	..	..	..	..	..	12 grains.
Alcohol	..	..	..	..	..	1 ounce.
Ether	..	..	..	..	..	1 "
Castor oil	..	..	..	..	..	2 drops.

The castor oil gives toughness and elasticity.

Collodion that is to be the medium of a sensitive salt, as in the wet collodion process for negatives, must have the castor oil omitted, and the solvents must be pure and of a proper strength. The ether should be of specific gravity .725, and the alcohol about .805 to .82. The higher the specific gravity of the alcohol the more water it contains, and the water introduced thus unwittingly by those who have no technical knowledge of these matters is a very important item in the preparation.

In cold weather about a tenth part of the alcohol may be omitted and a corresponding amount of ether added, that the solvents may be more volatile. But the amount of license in varying the proportions of the solvents is not very great without the sacrifice of desirable qualities. Ether, being the most volatile of the solvents, causes a more rapid setting of the film if in excess, and in coating large plates it may thus be impossible to get the whole film in a sufficiently uniform condition—the top setting before the bottom has drained. Excess of ether also causes the film to be tough and highly contractile—so much so, indeed, that it may spring off the plate. Collodion is used in surgery to form a protective film over wounds, and its powerful shrinkage after it has set is then advantageous. Excess of alcohol causes the film to be slow in setting, less contractile, and therefore more firmly adherent to the glass plate when such a support is employed; it makes the film more porous and soft, and therefore allows a more rapid penetration by any solution that may be applied to it. A greater excess of alcohol makes the collodion thick and glutinous. A certain proportion of water is often desirable

in collodion when it is to be employed as a medium for sensitive salts, as it makes the sensitive film more opaque and creamy, and therefore capable of giving a more vigorous picture. But too much water makes the collodion thick, and the film it yields is "reticulated" as if it had shrunk and formed a network of fine cracks, and it is so "rotten" that a gentle stream of water would wash it off the plate.

CHAPTER XII.

COLLODION POSITIVES AND NEGATIVES.

IT will be convenient after a few general matters to consider first the principles that govern the production of collodion positives, then to pass to wet collodion negatives, and finally to collodion emulsion plates.

The wet collodion process, whether for positives or negatives, is very different from the working of gelatine plates, both in theory and in practice. In a gelatine plate the bromide of silver, with a little iodide, is diffused through the gelatine, and by exposure to light and development the silver salt is reduced to the metallic state. But in a wet collodion plate the iodide of silver, with perhaps a little bromide, held in position by the film, has also a solution of silver nitrate in close contact with it, and in development it is chiefly the silver reduced from this solution by the developer that deposits itself upon the so-called latent image. The development of a wet collodion plate is therefore a process of intensification rather than development, as these terms are understood in connection with dry plates.

As the developer has to deal with a solution of nitrate of silver instead of with an insoluble silver salt, it must be very much weaker that the silver may be reduced to the metallic state only so slowly that it can select its place of deposition, and, in fact, would not be deposited at all except for the slight disturbance caused in the solution by the latent image in its immediate vicinity. Now a simple solution of ferrous sulphate or pyrogallic acid acts almost immediately upon nitrate of silver, giving a copious deposit of the metal; therefore it is necessary to restrain the action, and this is done by the addition of an acid.

* Alcohol is also an ingredient in wet plate developers, but it is added merely to facilitate the flow of the developer, and must be increased as the silver bath gets old and alcohol accumulates in it. The silver bath is the solution of nitrate of silver into which the collodionised plate is dipped to render it sensitive.

The collodion used has first to be “iodised”—that is, to have a soluble iodide, or more generally an iodide with a little bromide—dissolved in it, and it is customary to dissolve these salts in half the alcohol needed for the collodion, and to mix it with the solution of the pyroxyline in the rest of the solvents, only as may be required; for iodised collodion changes very much more rapidly than plain collodion.

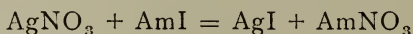
The general manipulations necessary for producing a wet plate picture (positive or negative) are as follows:—First the plate must be scrupulously cleaned and polished as with tripoli powder and alcohol or the equivalent; a little ammonia may be added to the tripoli and alcohol. The tripoli cleans by a polishing action, and the alcohol and ammonia dissolve greasy matters. If the glass is *thoroughly* clean, it may be at once coated with the iodised collodion; but most operators prefer to give a substratum of albumen, which makes certain the adhesion of the collodion film. For the substratum one may use—

White of ..	..	..	..	1 small egg
Water ..	..	..	..	1 quart
Ammonia ..	..	..	..	4 drops

and thoroughly mix and filter. The cleaned plate may be well rinsed with rain or distilled water, drained, and while still wet some of the albumen solution is poured over it. When the substratum is dry the plate may be used at once, or stored for use when required. The next operation is coating with iodised collodion, and this is done by pouring it on like varnish, taking especial care to rock the plate to and fro that the collodion may not flow in ridges. When the collodion ceases to drop from the glass, and the film is in just that condition that it will receive an impression when touched by the finger, the plate is ready for immersion in the silver bath.

Purest silver nitrate ..	30 to 40 grains or 60 to 80 grammes
Distilled water to ..	1 ounce or 1,000 c.c.

with perhaps dilute nitric acid added very cautiously until blue litmus paper is just changed towards a red tint by prolonged immersion in the solution, is all that would be needed if silver nitrate solution did not dissolve silver iodide. When the plate is immersed in the silver bath the iodides and bromides in the collodion react with the silver nitrate, thus—



forming the iodide and bromide of silver, which are the sensitive salts required. But if a simple solution of silver nitrate were used, the silver iodide would be dissolved out of the film, and the plate rendered useless. It is therefore necessary to add enough iodide to the bath to prevent its further action. Some prefer to saturate the bath with iodide of silver by putting a couple of coated plates into it; but it may just as well be done in a direct way. To this end dissolve the silver nitrate in a quarter the bulk of water required, and add to it about two grains of potassium iodide for every ounce of solid silver salt used, or half a gramme to 100 grammes. Then add the rest of the water, and a precipitate of silver iodide will be formed, for this salt is less soluble on dilution. After filtration and acidification (if necessary) as above, the bath is ready for use.

In manipulating wet collodion plates care must be taken to always keep the edge from which the collodion was drained downwards.

The collodion positive is the form of photograph invariably produced by peripatetic operators, because it is quickly made and rapidly dried, and can be handed in a finished condition to the customer a very few minutes after the exposure. This form of picture is called in America an Ambrotype, and if on enamelled iron is called a ferrotype.

As the deposit of silver represents the lights or whites, it is imperative that the metal shall be got as white as possible, and as the shadows are represented by a backing of black velvet or black varnish, it is important that the

deposit of silver shall be coarse grained enough to be transparent, and show something of the black backing through the parts that stand for the half-tones of the subject.

A collodion that gives a rather thin image is advisable, and as nitric acid tends to produce whiteness of the deposit, it may be added to the silver bath a little more freely than stated above, and it is used as the restraining acid in the developer. It is also advantageous to replace some of the ferrous sulphate of the developer by ferrous nitrate for the same purpose, but ferrous nitrate alone cannot be used, because it is so feeble a developer.

The following developer is recommended for positives:—

Ferrous nitrate ..	..	..	..	110 grains
Ferrous sulphate ..	..	..	..	60 „
Nitric acid ..	..	..	..	20 minims
Alcohol ..	..	..	..	quant. suf.
Water ..	..	..	..	4 ounces (Abney)

The plate is fixed by flooding it with a solution of potassium cyanide of strength about 25 grains to the ounce or 50 grammes to 1,000 c.c. The cyanide is preferable to hyposulphite in this case, because the deposit of silver is sufficiently granular to resist any appreciable action upon it, and a little reducing effect is often advantageous. It is more clean and more easily washed away than sodium hyposulphite. After fixing and washing, the plate may be dried over a spirit lamp flame.

If the film side of a collodion positive is presented towards the spectator, as it must be in a ferrotype, the image is reversed—that is, if the model was turned towards the right, the picture will represent him as facing the left. But if the film side of a glass positive is coated with black varnish, the glass side of the plate becomes the front, and there is no reversal.

A wet collodion negative may be regarded as an over-exposed and over-developed positive in which no trouble is taken to get the image any special colour. In the positive the surface is everything, but in the negative the appearance by transmitted light is the only important matter.

The collodion used must give a good film. The

iodisers may be varied very considerably, but generally the compounds of potassium, ammonium or cadmium are employed. Potassium salts do not dissolve freely in collodion, hence, although they can be employed, they are not so much used as they would otherwise be. Cadmium salts dissolve very freely, and they are stable, but they make the collodion glutinous—an undesirable condition that is modified by keeping the collodion for a few months after adding the iodiser. Ammonium salts dissolve easily, do not affect the collodion like cadmium salts, but they are unstable.

An iodide alone gives a hard picture; a bromide alone gives a flat picture full of detail. Therefore, when a black and white subject is to be copied, it is advantageous to use an iodide alone, but for ordinary half-tone subjects a mixture of bromide with iodide is preferable. A collodion suitable for positives is given by Hardwich as containing

Pyroxyline	1½ grains	} to each ounce.
Iodide of potassium ..	1½ „	

and the difference advised for negatives is

Pyroxyline	2½ grains	} to each ounce.
Iodide of potassium ..	2½ „	

Captain Abney gives formulæ containing ammonium iodide four grains or cadmium iodide five grains to each ounce containing six grains of pyroxyline.

The following is a specimen formula containing both ammonium and cadmium salts and a bromide:—

Ammonium iodide	3 grains
Cadmium iodide	½ grain
Ammonium bromide	1⅓ grains (Abney)

to each ounce containing six grains of pyroxyline.

In altering an iodising formula—or, indeed, any formula—care must be taken to introduce an equivalent quantity of the compound that replaces the other, and not an equal weight. The following chemical formulæ stand for equivalent quantities of the iodides and bromides of potassium, ammonium and cadmium, and the atomic weights put below them show the proportions that should

exist between the weights of the salts in exchanging one for another—

$2\text{NH}_4\text{I.}$	2KI.	$\text{CdI}_2.$	$2\text{NH}_4\text{Br.}$	2KBr.	$\text{CdBr}_2.$
290	332	366	196	238	272

If it is desired, for example, to replace one grain of ammonium iodide by cadmium iodide, the amount of the latter salt taken must be greater than that of salt replaced in the proportion of 290 to 366—that is, practically, one grain and a quarter of the cadmium salt must be used.

The action of the developer has already been described. As it has to mix with the nitrate of silver solution that adheres to the plate, it is not advisable, if it were possible, to use a considerable bulk of developer in a dish as is usual with gelatine plates, because the small quantity of nitrate of silver would be diluted to too great an extent. Unless it is desired to purposely reduce the vigour of the negative, the developing solution must not be allowed to overflow when it is poured on to the plate, for it would carry away some of the silver nitrate upon which the vigour of the resulting negative depends.

Either pyrogallie acid or ferrous sulphate will develop the exposed wet collodion plate. The former gives opacity and fineness of deposit, but the iron salt appears to be more powerful in getting detail, and is preferred, except in special cases. The usual strength of pyrogallie acid is one grain to the ounce (or two grammes to 1,000 c.c.), and if ferrous sulphate is used it may be from twenty to thirty grains to the ounce (or forty to sixty grammes to 1,000 c.c.), though these limits may be exceeded in both directions. A weak developer tends to produce contrast. A strong developer tends to softness, because the detail in the darkest parts is brought out before the lights have time to grow dense.

Whatever developer is used it must be retarded, and acetic acid is generally used for this purpose. Twenty minims of glacial acetic acid to each ounce of developer (or 40 c.c. to 1,000 c.c.) is effective; half this quantity or even less may be used, but the development is liable to be irregular, and stains may be produced.

The developing agent plus the restrainer, with just enough alcohol to make the solution flow easily on the plate, gives the simplest solution available. Many modifications have been suggested, chiefly with regard to the ferrous sulphate developer. Instead of sulphate of iron the double sulphate of iron and ammonium may be employed, or copper sulphate may be used in addition to the ferrous sulphate, and in each case the solution is made more stable. Sulphate of iron solutions in ordinary bottles slowly oxidises, and thus loses its developing power.

A wet collodion negative as developed is often too thin, and requires intensification or "re-development." This is simply a continuation of the developing process after washing the plate, but as no more detail is wanted the redeveloping solution may be more restrained. No alcohol is needed, because the simple aqueous solution will flow well over the washed plate, but a little silver nitrate must be added to supply the metal for deposition upon the image. A few drops of a solution of silver nitrate containing ten grains to the ounce or 20 grammes to 1,000 c.c. is added to the re-developer immediately before it is applied to the film.

Other methods of intensification, such as those given for use in connection with gelatine plates, are available after fixing; and these processes have the advantage, or it may sometimes be a disadvantage, of producing a certain and proportional result if properly used.

For fixing collodion negatives hyposulphite of soda is to be preferred to potassium cyanide for the same reason that it is preferred for gelatine plates, though there is less probability of the cyanide attacking the image of a collodion film. The hyposulphite of soda may be four ounces to the pint or 200 grammes to 1,000 c.c., and the cyanide may be 25 grains to the ounce or 50 grammes to 1,000 c.c.

CHAPTER XIII.

COLLODION DRY PLATES AND SENSITISERS.

IN the wet collodion plate the sensitive film is moist with a solution of silver nitrate, and in the last chapter the importance of this silver solution for development was pointed out. The question at once rises—May not this silver nitrate be washed off the plate so that the plate may dry without crystallisation on its surface, the dry plate be exposed, and the silver nitrate restored at development, as, indeed, silver nitrate is added in redevelopment? If the silver solution was of no use except in development this process would be practicable, but as a washed plate is very much less sensitive than one not washed we have proof that the silver nitrate solution produces an important action during the exposure. How the silver nitrate causes this increase of sensitiveness is not known, because it is not known how light acts in producing a developable image.

If pure chloride of silver is dried by those careful means that only the chemist knows how to employ, it may be exposed to light without changing colour. But chloride of silver that is wet is partially decomposed by the action of light, and chlorine is set free. If the chloride of silver is wet with a solution of nitrate of silver, the darkening by the action of light is more rapid. In this case the water and the nitrate of silver solution are "sensitisers," and the latter is a more powerful sensitiser than the other.

In 1862, Poitevin showed that certain substances were not decomposed by light unless an absorber of the element liberated (chlorine, in the case of silver chloride) was present. In 1865, H. Vogel took up the question, and from that time he has made many experiments on the subject. He showed that the sensitiser was probably necessary, and certainly advisable, to enable light to produce a

developable image ; and that a great many substances that absorb or chemically combine with the halogens (iodine, bromine, chlorine) act as sensitisers, but that the power of sensitising is not proportional to the vigour of combination with the halogens. Moreover, the sensitiser that is most active toward silver iodide is not the most active towards a mixture of iodide and bromide as generally used in the collodion process.

It is assumed by many that because most sensitisers can act after the manner of (in chemical language) reducing agents, and because many reducing agents act as sensitisers, that the action of the sensitiser is a reducing action, and that its function is to take up the halogen liberated by light in the production of the developable image. The sensitiser may act in this way when decomposition is produced by light, but it has not yet been proved that any decomposition of the silver salts takes place in the production of the developable image, and the action of the sensitiser in this case is therefore obscure. If the sensitiser performed this duty and nothing more, the most powerful reducing agent should be the most powerful sensitiser, and this has been found by H. Vogel not to be so.

On a wet collodion plate the nitrate of silver solution adhering to it is necessary during exposure, and the nitrate of silver may not be dried on the plate, because it would crystallise and produce irregularities. If a dry collodion plate is desired, therefore, the nitrate of silver solution must be replaced by some other sensitiser that will dry evenly. For this purpose the following substances or extracts of them, have from time to time been recommended :—Gelatine, tannin, gallic acid, albumen, tapioca, rice, eggs, raisins, honey, sugar-candy, raspberry syrup, jelly, ale, porter, gin and water, stout, wine, tea, coffee. This list is the result of a want of scientific method on the part of many photographic experimentalists. Instead of working with pure substances, or mixtures of pure substances, uncertain household preparations were often employed, and when another experimenter essayed to prepare plates after the formula given, he met in many cases with failure, for the gin and water of one locality is very different from the

gin and water of another, although the consumers take every care to add exactly the same proportion of water.

These substances that we have called sensitisers were generally called "preservatives," and were so called before their sensitising action was clearly understood. Moreover, "sensitising the plate" is an expression generally applied to the change that takes place when it is immersed in the silver bath. The word preservative is very justly used, for the material employed as a sensitiser must be more than a sensitiser—it must form a protective coating over the film.

To prepare dry collodion plates by the "bath process," the plates are treated much as already described until they are put into the silver bath. That a more complete action may take place, the plate remains rather longer in the bath; it is then removed, washed, flooded with the preservative, and dried.

The exposure necessary may be from that needed for a wet plate to twenty or thirty times as long, according, partly, to the developer used. When about to develop, the preservative, having done its work, is washed off, as in some cases it would interfere with the further operations. Dry collodion plates are preferably developed like gelatine plates, and with similar developers.

It will be observed that the action of the silver bath in preparing a dry collodion plate is merely to form the silver salt in the film. As the bromide and the iodide are added to the collodion, it appears but natural to add the nitrate of silver too, and so transform the "iodised" or "bromised" collodion into a collodion "emulsion." The silver bath is then dispensed with, for the sensitive salt is in the collodion. The first collodion emulsion that gave useful results was prepared in 1864, and was due to the labours of Sayce and Bolton, who used bromides only in its preparation.

The simplest method of preparing a collodion emulsion is to make a collodion with a suitable quantity of a bromide, but with enough alcohol omitted from it to dissolve the silver nitrate in, and to add the solution of the silver nitrate in the alcohol with constant stirring or shaking. The silver nitrate added must be a little in excess of that

required to form silver bromide with all the bromide present. The emulsion so produced is not in its best condition, but should stand for from twelve to twenty-four hours to "ripen." At the end of this time the emulsion is more creamy and more sensitive, and prepared glass plates may be coated with it. When the film has set, the plate is washed and the preservative applied.

Instead, however, of washing each individual plate, the emulsion itself may be washed. To effect this the solvents are evaporated or distilled off, and the residual pellicle is washed with water. The water remaining after squeezing is washed out with alcohol, and the pellicle is redissolved for use. Plates coated with such an emulsion do not need washing, and can be used without a preservative, but a preservative is recommended if reliable working is considered a desideratum.

CHAPTER XIV.

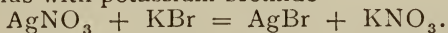
MANUFACTURE OF GELATINO-BROMIDE PLATES.

THIS is not the place to enter into the technicalities of the making of gelatine plates, as this volume is intended for the photographer and the student, rather than for the manufacturer. The photographer now-a-days does not make his own plates any more than he makes his own apparatus, though, indeed, he may do both as occasion may require.

We have already seen what a collodion emulsion is, and how it may be prepared; a gelatine emulsion is quite analogous, but instead of pyroxyline dissolved in alcohol and ether there is gelatine dissolved in water, and instead of the film on the coated plate solidifying by the evaporation of the solvents, as in collodion, it solidifies to a jelly by the cooling of the warmed mixture, and afterwards dries slowly. But there is a great difference between collodion and gelatine in the influence that the medium has upon the sensitive salt; for while collodion has so little effect that it may be considered inert, gelatine is an energetic sensitiser. The collodion emulsion ripens by standing for a few hours; but the gelatine emulsion, by a few days' warming or a few minutes' heating to the temperature of boiling water, is exalted in sensitiveness to a degree that was incredible fifteen years ago.

It appears that the first formula for making a gelatino-bromide emulsion that was published was due to Dr. Maddox, who, in 1871, made known some experiments he had performed with the object of replacing collodion with gelatine.

When a soluble bromide is mixed with silver nitrate, silver bromide is produced with the nitrate of the other base. Thus with potassium bromide—



The importance of washing away the nitrate was pointed out by Joshua King in 1873.

In 1878, Charles Bennett prepared a very sensitive gelatine emulsion, and by its means produced some instantaneous negatives that astonished those who saw them. Bennett's improvement consisted in keeping the emulsion at a temperature of about 90° Fahr. for six or seven days. This tedious procedure was shown to be unnecessary by G. Mansfield in the following year. He heated his emulsion by means of boiling water, and got sensitiveness in minutes instead of days. The highly sensitive condition of silver bromide is obtained only when the heating takes place in the presence of gelatine, and apparently only when the soluble bromide is in excess, so that some remains after it has changed the silver entirely into bromide. The emulsion when first prepared is orange coloured if looked through, but after cooking it transmits grey light. The change of colour indicates that its absorptive action upon light is different, and as a matter of fact the "boiling" of the emulsion confers a slight sensitiveness to yellow and red light.

Gelatine jelly when kept melted for a considerable time, or when heated to the temperature of boiling water for a short time, loses its power of gelatinising. W. B. Bolton had, in 1874, recommended that only a little of the gelatine should be used in preparing the emulsion, and the rest added afterwards. This modification became of great importance, and was speedily adopted when gelatine emulsions were heated to gain sensitiveness. Many experiments have been made to get rid, as far as possible, of the gelatine in which the emulsification and boiling takes place by means of centrifugal apparatus, so that the pure silver salt in its high state of sensitiveness may be mixed with fresh gelatine. This process appears to be very desirable, but it is certain that excellent plates can be made without it, and it seems that practical difficulties tend to deter most manufacturers from adopting the method. The emulsion prepared by Thomas and Co. for their plates is separated by centrifugal machines.

The variations in the methods of making gelatino-bromide emulsions are innumerable; many formulæ have been published, and manufacturers are careful not to allow

the details of their processes to get known. The following method of preparing a slow emulsion for landscape work by W. K. Burton will serve as an illustration, and it is given in his own words. He says :—

“ I will give a formula, although I claim no particular merit for it, except that I have tried so to adjust the details that the process may be as simple as possible, and that the chance of failure may be reduced to the minimum.

- | | |
|--|--------------------|
| A. Nitrate of silver, 200 grains; distilled water, 3 ounces. | |
| B. Bromide of potassium, 160 grains. | |
| Iodide of potassium, 10 grains. | |
| Nelson's No. 1 gelatine, 40 grains. | } Water, 3 ounces. |
| Hydrochloric acid, 2½ minims. | |
| C. Hard gelatine, 150 grains. | |
| D. Hard gelatine, 150 grains. | |

“ The gelatine of B is allowed to soften. At the same time water may be poured over the lots of gelatine C and D (kept separate one from the other) to let them swell.

“ A and B are now heated to 120° Fahr., and A is poured into B slowly, with vigorous stirring. The emulsion thus formed is allowed to stand for ten minutes with occasional stirring. Meantime, as much of the water is squeezed out of the gelatine C as is possible by wrapping it in a towel or similar piece of cloth, and wringing the cloth round.

“ After ten minutes the emulsion (having been allowed to remain without stirring for at least two minutes to allow any granular bromide which may have been formed to subside) is poured over C, heat being, if necessary, applied to melt the gelatine. When the gelatine and the emulsion are thoroughly incorporated, the jar containing them is set on one side to allow the whole to set into a stiff jelly. In cold weather there is no difficulty in getting the emulsion to set, but if the weather is warm it should be allowed to stand in a vessel containing water with a lump or two of ice in it. Once thoroughly set, the emulsion is washed in any of the well-known ways, being either squeezed through canvas, or otherwise cut into small fragments. When it has been washed thoroughly and drained so that no more water will drain from it, D (having had as much

water as possible wrung out of it) is added. The whole is melted up, and one half ounce of pure alcohol is added, when it is ready for coating plates.

“The quantity of emulsion that I have described should serve to coat a dozen 10 by 8 plates. A skilled coater could make it cover a dozen 12 by 10 plates without any part being too thin.”

The washing of a gelatine emulsion is preferably done by squeezing it under water through netting of small mesh. It is thus finely divided, and the water readily gains access to every part. Twice squeezing through netting under clean water and well washing under the tap will probably be sufficient. If the excess of soluble bromide (which is necessary during the boiling in order to obtain great sensitiveness) is not washed away, a considerable loss of sensitiveness will result.

A fairly sensitive emulsion may be prepared by means of ammonia and without boiling. The ammonia should be in such quantity as to just re-dissolve the oxide of silver that it precipitates when first added to the nitrate of silver. This method has the advantages that all the gelatine may be added at once, as the temperature of about 95° Fahr. for the short time required does not materially decompose it, and that a slightly acid or slightly alkaline condition of the gelatine, or any of the salts used, exercises no detrimental effect.

CHAPTER XV.

ORTHOCHROMATIC PHOTOGRAPHY.

THE visibility of colour obviously depends upon the capability of the human eye. If the seeing power of the majority is taken as the standard, there will be found a very large number of deviations. Some will see more in the sense of being able to distinguish colour that is no colour to the majority, and others will see less. Those who are called colour-blind have a still more limited range. In referring, therefore, to the visibility, luminosity, or the intensity of light, it is understood that reference is made to the seeing capacity of the majority of individuals.

The intensity and the chemical activity of light are far from proportional, and advantage is taken of this fact in selecting a light that shall be comparatively safe for manipulating sensitive materials in. A yellow light may be made quite bright enough for such operations, but yet of such feeble chemical power that the most sensitive plates are not apparently affected by exposure to it for a few minutes. This is a great convenience, but the difference between visibility and chemical effect is sometimes disastrous in photographic results. The yellow of a picture which is light to the eye may be shown dark in a photographic reproduction; dark red is rendered as black, while dark blue may produce the same effect as white or light grey. Such a total change in the disposition and proportion of light and shade generally makes an ordinary photographic reproduction of a brilliantly coloured picture worse than useless unless the photographer manipulates his negative to correct these faults.

If the chemical activity and the visibility of light were uniformly proportional, these anomalies would cease; and accordingly attempts are made to cause the chemical activity to approach more nearly to the visibility. To

make the two exactly proportional is not yet possible, and it does not appear that it ever will be possible. The differences, however, can be very markedly and usefully diminished.

If a plate could be made perfectly orthochromatic, any light would be as good as any other to work with in developing, but the light would have to be so reduced that its effect upon the plate would be practically nothing. But as perfect orthochromatism is impossible, there is always one or, it may be, two tints that have their visibility in excess of their chemical activity, and this is a guide for the light to be selected for developing, etc. Generally a dull, deep red is as safe as any light—a deep ruby glass, or this with cobalt glass in addition. Yellow is to be avoided, for the chief aim of operations that tend to orthochromatism is to increase the sensitiveness to yellow light.

The only perfect colour scale for the comparison of results is the spectrum. In figure 46 the vertical lines

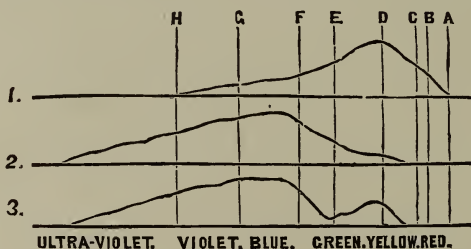


FIG. 46.

stand for the Fraunhofer lines, and are lettered accordingly. The curves represent the opacity produced; they rise to represent a larger effect, and fall to show a diminution. Number 1 shows the visibility of the spectrum, number 2 the effect produced by exposure and development of an ordinary gelatino-bromide plate, and number 3 the result when the plate is prepared with an ammoniacal solution of rose Bengal. The curves are taken from C. H. Bothamley's excellent papers on the subject.

It will be observed in the figure how that yellow, which

is the brightest colour, produces scarcely any effect upon the unprepared plate, but the plate that has been treated with the dye is very decidedly more sensitive to the yellow, though it remains so very much more sensitive to the blue and violet that practically little difference would be observed in using such a plate. But by interposing a yellow glass or coloured collodion film between the object and the plate, it is possible to stop a large proportion of the blue and violet light without markedly impeding the yellow. Or by the use of a yellow light for the illumination of the object the excessive sensitiveness of the plate for blue may be counter-balanced. By this means a very great improvement in the representation of the apparent brightness of colours is effected.

There are very many dyes that produce a change in the sensitiveness of the silver compound, but each has a different effect. The amount of dye used in all cases is very small. C. H. Bothamley says that when the dye is added to the emulsion, 2.4 milligrams per 100 c.c. of melted emulsion is found to be sufficient. He states that the most efficient processes are those in which the prepared plate is dipped into a dye solution, and recommends an immersion for two or three minutes in a solution containing—

Dye solution (1 part in 1,000 parts of water)	1 to 2 volumes.
Ammonia (10 per cent.)	1 volume.
Water	8 volumes.

Allow the plate to drain and dry in a pure atmosphere. The ammonia may be omitted if erythrosin or rose Bengal is used, but five or six times the exposure will then be required. Erythrosin or rose Bengal sensitise for yellow, and cyanine for red, but the latter is better when used in conjunction with either of the former, and in this case also the orthochromatism is more perfect. Plates treated by these processes are liable to give excessive density on development, but this, of course, is easily obviated.

The effect of certain coal-tar dyes in producing a change of silver sensitiveness in silver compounds was discovered in 1873 by H. W. Vogel. His idea seems to have been that the light stopped or absorbed by the dye was

caught or trapped by it, and so was enabled or obliged to act upon the silver salt in its immediate presence. That yellow light, for instance, which would, under any ordinary circumstances, pass by the particles of silver compound, being retained by the dye, was made effective like the blue light that the silver salt would absorb unaided. But the effect of light upon the silver salt and upon the dye cannot be so separated. Some dyes that are effective form a compound with the silver bromide that may be freed from the gelatine it is prepared in and introduced into fresh gelatine without losing its changed properties; or a plate that has been treated with a solution of suitable colouring matter may be washed without removing the dye, because it has entered into combination with the silver salt.

In January, 1883, Tailfer and Clayton secured a patent for the preparation of orthochromatic plates by means of an ammoniacal solution of eosine, and Edwards and Co. hold the right in this country to make plates under this patent.

It is obvious that orthochromatic plates are more expensive to prepare and more troublesome to use than the ordinary plates, and it is therefore not advisable to employ them when there is not a marked advantage to be gained by them. It may be said that they are indispensable for photographing objects that present a variety of brilliant colours, or for getting a negative by means of a yellow light, such as gaslight, when the time of exposure cannot be prolonged, as in portraiture. An individual whose face is covered with yellow freckles may be taken on an orthochromatic plate with advantage, because the yellow is little different from black to the common gelatino-bromide plate. These special plates are also to be preferred for yellow or reddish objects in photo-micrography.

But it is very doubtful whether much advantage is gained in average landscape work by the use of them. The distance is certainly rendered more clearly, but a sharp delineation of distant objects is not the prime desideratum in a picture.

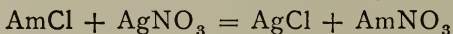
It would appear that, as gelatine dry plates not specially prepared are slightly sensitive to yellow, if a

coloured screen were used to reduce the amount of blue transmitted to the plate, the proportion of effect produced by yellow light might be increased to a useful extent. Doubtless this is possible, but as a matter of fact a coloured screen may be used of so deep a tint that the exposure has to be increased twenty times without any perceptible improvement in the rendering of colours. The sensitiveness to yellow and red is presumably so small that increasing its effect from ten to twenty times makes no perceptible difference.

CHAPTER XVI.

SILVER PRINTING.

THERE are many methods of photographic printing, but the oldest of those methods that have ever been commercially important, and the process which still enjoys the largest share of popularity, is that in which the sensitive material consists of a layer of albumen which contains certain silver salts, and is supported on paper. The albumen is mixed with a certain proportion of ammonium chloride before the paper is coated with it, and, after the layer of albumen is dry, it is made sensitive by floating the paper on a solution of silver nitrate of a strength generally of from 35 to 50 grains to the ounce. The effect of the silver solution is manifold and somewhat obscure. It acts upon the ammonium chloride in the albumen, and changes it completely into silver chloride, with the simultaneous production of ammonium nitrate, according to the equation,



The silver chloride is insoluble, and remains in the albumen film; the ammonium nitrate is soluble in the water, and passes out, as far as it has time, into the silver bath. The nitrate of silver also acts upon the albumen itself, producing an insoluble compound, the nature of which is but little understood. The production of this compound is, however, of vital importance, for if the albumen were not made insoluble it would be washed off the paper. The stronger the solution of silver nitrate employed, the more insoluble and less penetrable does the albumen become, so that a longer floating is necessary with a strong bath than with a weak one to ensure the thoroughness of its action. The excess of silver nitrate in the film, and the greater part of that which clings to the surface, remains in the prepared paper; and in the ready sensitised paper now

so largely used, citric acid or some other preservative is also introduced.

With such a complication it is not to be wondered at that the results are uncertain, and that the changes produced are not understood. But add to this the need of toning to get an acceptable colour instead of a disagreeable red, and we find in this process, perhaps, the greatest number of scientific problems that even photography has ever brought together. It cannot be denied that the majority of prints made by this process are not stable; some last a month or two, some a year or two, a few are apparently unchanged after a decade or two, and still fewer have possibly lasted for a generation; but no one can with certainty say why this difference exists. Any hyposulphite of soda remaining in the print or gaining access to it seems an important element in its destruction. Yet the various methods that have been proposed for getting rid of the hyposulphite do not seem to be appreciated.

Under these circumstances it would be consistent with the aim and scope of this work to pass by this process of printing with a mere mention, and especially as there are other methods of printing that have been commercially important for many years, and give results of an undoubtedly permanent character, being founded on well-known scientific principles. But although more than forty years of patronage, and an enormous practice in this process, coupled with very many investigations by able experimenters, have failed to establish silver printing on albumenised paper on any but the most unsatisfactory foundation, the fact that the majority of prints are still produced by this process obliges us to consider it.

The use of albumenised paper for photographic printing appears to have been introduced by H. Pollock, or by Le Gray, shortly before 1851, as the second edition of R. Hunt's "Manual of Photography" bearing that date describes it as if it were a new and little-tried process. A committee of the Photographic Society state in a report made in 1855 that they had examined silver prints on albumenised paper which were seven years old. This takes us back to 1848. It is probable that the idea of

employing the albumen was to get brilliancy of image by keeping it on the surface of the paper instead of producing it in the paper, as had been done as early as 1802, when Wedgwood and Davy published their experiments. The albumen, however, profoundly alters the nature of the picture.

The albumen used for coating the paper is the whites of eggs, and to this is added ammonium chloride dissolved in a little water. The quantity of the salt used may vary between wide extremes, from five grains to forty grains per ounce, but W. K. Burton says that from what he can gather "eight grains to the ounce is a common quantity of chloride of ammonium to use." After adding the determined proportion of the salt the albumen is beaten up very thoroughly to cause the separation and easy removal of animal membrane, and get a homogeneous solution. Insufficient frothing will not allow of the subsequent removal of membranous matter, and this will give rise to streaks on the paper.

After settling, the mixture is filtered through muslin or flannel and poured into a flat dish. The sheets of paper to be coated are floated upon the solution and hung up to dry. If a piece of albumenised paper is put into water the coating will be readily dissolved off, and to prevent this in the after treatment of the paper it seems that some early photographers advocated ironing the coated paper with a hot iron to coagulate the albumen. This, however, is quite unnecessary, as the albumen is made insoluble in the sensitising.

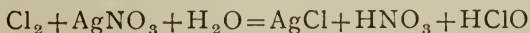
The albumenised paper is made sensitive as described above, and it is only necessary to add that the coagulation of the albumen by means of the silver solution is not a mere coagulation such as takes place when an egg is boiled, but it is the result of the formation of an insoluble compound of albumen containing silver called silver albumenate. The chemical formula that has been suggested for this compound is $C_{72}H_{110}Ag_2N_{18}SO_{22}$.

Thus sensitised albumenised paper when it is ready to be exposed to light is coated with a mixture of silver albumenate, silver chloride, silver nitrate, ammonium nitrate,

and probably, when the ready sensitised paper is employed, we must add citric acid to the list.

Now, complication does not of necessity lead to uncertainty, but let us see what is known about the effect produced by light upon these compounds, leaving out the ammonium nitrate and citric acid, as they may be unchanged.

Scheele showed that when chloride of silver was exposed under water the silver compound lost chlorine, and what remained was darkened in colour. Our knowledge of this matter is very little, if any, in advance of Scheele's, for no one has satisfactorily prepared a definite compound of silver with chlorine containing less chlorine than the ordinary white chloride. When albumenate of silver is exposed to the light it darkens to a reddish colour, but the chemical change that takes place is altogether obscure—indeed, the chemistry of albumen itself rests almost entirely upon an empirical basis. It appears probable that the function of the nitrate of silver is rather to assist the decomposition of the other compounds than to contribute directly to the formation of the colour of the image. It perhaps takes up the chlorine liberated from the chloride of silver and prevents it from injuriously affecting the picture, besides causing it to supply more chloride of silver. This change may be expressed thus:—



The HClO is hypochlorous acid, a compound that has been shown to be actually produced when silver chloride and nitrate are exposed to light together. The nitric and hypochlorous acids introduce fresh complications into the problem. Therefore, when sensitised silver paper is exposed to light under a negative, an image is produced which consists of two constituents, and perhaps more, neither of which is known to be of fixed composition.

When a silver print is plunged into a solution of hyposulphite of sodium to fix it, the coloured albumenate of silver is very little affected, but the darkened chloride is dissolved in great measure, leaving a quantity of metallic silver behind that is probably equivalent to the chlorine expelled from it by the exposure to light. Hence the

image is considerably reduced in intensity, and what remains is of an unpleasant reddish tint. To obviate the reduction in intensity it is necessary to expose under the negative until the depth of colour produced is much darker than is desired in the finished print, and to correct the colour it is usual to "tone" the print.

It is customary and advisable, though not necessary, to tone the print *before* fixing. Toning consists in depositing a fine powder upon it under such circumstances that the powder itself reflects blue light, and this blue, together with the brownish red of the original, gives the rich tints of a skilfully-made silver print. If the print were fixed in an acidified solution of sodium hyposulphite, it would be toned to a rich brown, because the sulphur precipitated by the action of the acid would cling to the image. But sulphur toning, though very common in the early days of albumenised paper, is not to be recommended, because the result is probably more liable to fade than when gold or platinum is used.

Gold toning is invariably resorted to at the present day. It is possible to get gold precipitated as a blue or as a red powder, according to the size of the particles. Very slow precipitation gives the finer particles which appear red, while quicker precipitation gives less fine particles which appear blue. Therefore, though it is advisable to add some substance to the solution of chloride of gold to cause it to act regularly, care must be taken that the toning action is not too much retarded, for then red gold would be deposited, and the addition of red to the red image would give little or no change of colour. It is possible to make a toning bath so slow in action that it cannot over tone, but this is not an advantage, because, if the change of colour *cannot* go too far, it will probably not go far enough. Obviously, from these remarks, the amount of colour change in toning is not an index of the quantity of gold in the finished print.

Whatever formula for toning is employed, it is advisable to neutralise the free acid generally present in chloride of gold by shaking it up with powdered chalk and filtering in an hour or so. If this is not done, as an uncertain quantity

of acid is present, an uncertain solution is prepared, and the results will not be uniform. When acetate of soda is used, the chalk may be added with the acetate.

To prepare prints for toning, they should be washed until the free nitrate of silver is removed—four or five changes of water will generally suffice—and then put into a weak solution of common salt (containing a pinch or so to the pint), and finally washed about twice. The salt reddens the prints, and makes the change of colour in toning more obvious. They are then immersed in the slightly warm toning bath. The following formulæ for toning baths are only examples of many others:—

Borax	48 grains	or	12 grammes
Chloride of gold ..	1 grain	„	0.25 „
Water	8 ounces	„	1000 c.c.

To be mixed only as required.

Sodium acetate ..	20 grains	or	5 grammes
Chloride of gold ..	1 grain	„	0.25 „
Water	8 ounces	„	1000 c.c.

To be mixed at least two days before use.

Sodium carbonate ..	10 grains	or	2.5 grammes
Chloride of gold ..	1 grain	„	0.25 „
Water	8 ounces	„	1000 c.c.

Must be used soon after mixing.

Strict care must be taken that no hyposulphite gets into a toning solution. An imperceptible amount adhering to one's fingers or to the dish (if it has unwisely been used for fixing) is quite sufficient to stop toning. It may be found advantageous to increase or diminish the water in the above formulæ to adjust the time in which a satisfactory tone is obtained.

After toning, the prints are washed in two or three changes of water, and then fixed. Hyposulphite of soda, four ounces to the pint, or 200 grammes to 1000 c.c., with enough ammonia or sodium carbonate to make the solution alkaline, is a good formula. The solution must not have been used before, and it must not be overworked. It appears that a want of permanency can be more often traced to imperfection of fixing than to any other cause. The prints are then washed thoroughly.

Any hyposulphite remaining endangers the permanency of the prints. There are several reagents that will oxidise a small amount of hyposulphite remaining after a few changes of water into harmless compounds. W. H. Newton used acetate of lead, and J. Spiller suggested peroxide of hydrogen. But probably the most convenient hypo-eliminator is a weak solution of iodine, which was strongly recommended by H. W. Vogel. The author advises the use of this reagent in the following manner, that the oxidation of the hyposulphite may be completed with certainty, and that an unnecessary prolongation of the action of the iodine may be avoided, for doubtless all hypo-eliminators have a tendency to attack the picture itself.

Make a strong solution of potassium iodide in water, and dissolve in it as much iodine as will give a practically black liquid. Add this a drop or two at a time to a sufficient bulk of water for the prints to be treated in until the water is tinted to a pale sherry colour. The prints are washed in five or six changes of water during half an hour or so, and are then put into the iodine solution. If the prints take a uniform and persistent blue colour on their backs all is well; otherwise they must be put into another similar iodine bath as soon as the colour of the first has been discharged. The blue colour shows excess of iodine, and therefore absence of hyposulphite. To get rid of the blue colour a few drops of a solution of sodium sulphite may be added to the water, and the prints are then rinsed and dried.

But whatever care is taken in producing a silver print on albumenised paper, one can never be certain that the result will be permanent. Looking at photographic printing from a scientific point of view, it would be far better to use the albumenised paper process for temporary proofs only, as mere tests of the effects of negatives, and to invariably resort to a permanent process for work that is to be preserved. By a permanent process we mean one in which the picture will last as long as the paper that supports it, the permanency being comparable with that of oil or water colour paintings, or impressions made in the usual sorts of printer's ink.

There are other methods of silver printing which are adapted to special purposes. When many prints are wanted from one negative, as for publishing purposes, it is very desirable to shorten the time necessary for their preparation. This is accomplished in a very practical manner by using paper coated with a slow gelatino-bromide emulsion. An exposure of a few seconds is followed by development, &c. Machines have been constructed by which the various operations are done automatically. Such a process is exceedingly useful also in making direct enlargements, for a direct enlargement on albumenised paper requires a cumbrous optical apparatus and such weather as we rarely get in this country.

Gelatino-bromide paper is now largely used. The chief points concerning the development of it, in which the treatment varies from the development of negatives, are that care must be taken to keep the whites pure, and stains of all sorts must be strictly eliminated. By using a well restrained and dilute developer, and by putting the print direct from the developer into dilute acid, these desiderata are secured, and the process is well under control.

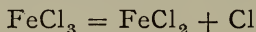
Paper coated with an emulsion of chloride of silver is also prepared, and this has the advantage that many gradations of colour can be obtained on it. By increasing exposure considerably, perhaps a hundred times or more, and developing with a sufficiently restrained developer, a red print is obtained which may be toned with gold.

It is natural to expect that these developed prints should be as permanent as negatives. The image consists of metallic silver, and not, as in the albumenised paper print, of a large proportion of an organic salt of silver. If properly prepared, perfectly fixed and carefully washed, such prints are entitled to be considered as what is ordinarily known as permanent. It cannot be denied, however, that published experiments indicate that under some (not ascertained) circumstances, prints produced by these processes are liable to change.

CHAPTER XVII.

PRINTING IN SALTS OF IRON.

PASSING from the salts of silver, which are exceptionally valuable, but also surpassingly treacherous, we find on turning to the salts of iron simplicity and certainty. When ferric chloride is exposed to the light in the presence of organic matter, it is decomposed, chlorine is given off, and ferrous chloride remains, thus :—



Other ferric salts are decomposed in a similar way, and the choice of the compound to be used is a matter of practical convenience rather than of theoretical significance.

In 1842, Sir J. F. W. Herschel published several processes by which this change in iron salts could be made serviceable for photographic printing. He found the double citrate of iron and ammonium to be more sensitive, and to have other advantages, and no one since has found a more suitable ferric salt for most of the processes about to be described.

Paper may be soaked in, or floated on, or brushed over with, a strong solution of this salt. The author prefers the soaking, as being more certain, and giving a paper that yields a more vigorous print. The paper when dried by a gentle heat is ready to expose under a negative. The exposed print may be developed in many ways, but the most useful probably is the application of a solution of ferricyanide of potassium. The crystals should be washed and dissolved only just when required, and the addition of a little citric acid is advisable, especially if the water used is hard. The ferricyanide gives a dark blue

insoluble compound of ferrous ferricyanide with the ferrous salt that the exposure has produced, but the unchanged ferric salt is merely washed off the paper. The developed print is washed in water slightly acidulated with citric acid (just to taste sharp), rinsed in plain water and dried. A print so prepared has a very brilliant colour, and by mounting, and applying a moderate quantity of encaustic paste to its surface, there results as brilliant a blue print, probably, as any process will furnish.

The ferrous ferricyanide, which is a sort of Prussian blue, is soluble in potassium ferrocyanide. It is decomposed by alkalies with the production of the alkaline ferrocyanide which dissolves, and hydrate of iron which remains in the paper, and is easily soluble, after washing, in hydrochloric acid.

A commercial paper for getting blue prints is prepared in considerable quantity especially for the use of engineers and others for copying drawings. This is coated with a mixture of the ferric ammonium citrate and ferricyanide of potassium, and after exposure needs only washing with water to develop and fix the image. Unless such paper is used within a short time of its preparation, it will not give clean and brilliant prints.

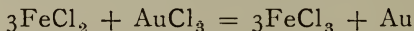
It will be observed that if an ordinary drawing is copied by the above process the copy will have a blue ground with white lines, a matter of little importance so far as working from the copies is concerned. But if ferrocyanide of potassium is used instead of the ferricyanide, there will be to a certain extent a reversal of these conditions. The ferrocyanide gives Prussian blue with the unchanged ferric salt, and a white compound with the ferrous salt. But this white product ($K_2Fe_2C_6N_6$) so very soon takes up oxygen from the air and turns blue that the actual result in practice is a light blue or greenish blue as it is described on account of the yellow ferrocyanide being present. The rapid changing of this salt, and the fact already mentioned that Prussian blue is soluble in ferrocyanide of potassium, make this process less easy to carry out than the one previously described. Herschel gave both methods of development, and the use of the ferrocyanide for getting a

positive print from a positive has been since improved by Pizzighelli and by Pellet and Co. Pellet's formula is

Oxalic acid	..	..	5 grammes.
Ferric chloride	..	..	10 grammes.
Water	..	..	100 c.c.

A well-sized paper is coated with this solution and dried. After exposure, development takes place in a 15 to 18 per cent. solution of ferrocyanide of potassium, and after thorough washing in water, the print is put into water containing 8 to 10 per cent. of ordinary hydrochloric acid, which has the effect of clearing the ground and slightly darkening the image. A final washing and drying complete the operations. This method has the advantage of giving a cleaner print than if the citrate as proposed by Herschel were employed.

The paper merely coated with the ferric ammonium citrate may be developed after exposure with a neutralised solution of gold chloride, washed with water and dried. This is Herschel's "chrysotype." The ferrous salt produced by the light reduces the gold to the metallic state, and the image is of the blueish colour of gold so precipitated. In reducing the gold the ferrous salt is changed back into ferric; if the chloride of iron were used, the developing operation would be expressed thus:—



Nitrate of silver in dilute solution may also be used for developing, and the image is then obtained in metallic silver.

CHAPTER XVIII.

PLATINOTYPE.

OF all methods of printing by means of iron salts this is the most important, for it gives a good image of as permanent a character as can be imagined. Moreover, certainty is not gained at a sacrifice of beauty, for those who are most entitled to judge of artistic merit admire platinum prints while they only put up with ordinary silver prints.

To prepare paper for platinum printing in a successful way requires considerable skill, a certain amount of chemical knowledge and an ability to perform analyses. The modern tendency is to leave the manufacturer to prepare sensitive materials, and for the photographer to concentrate his attention upon the actual making of pictures, and it appears very unlikely that when printing in platinum ceases to be a patented process, photographers will do anything more than they do at present towards preparing their own sensitive paper.

The perfection and practical success of the platinotype process as at present practised are due almost entirely to the labours of W. Willis. The improvements upon his first successful method have been chiefly simplifications, eliminating one after another the ingredients not of prime importance.

The usual method of platinotype printing consists in coating paper with a solution containing ferric oxalate and the chloride of platinum which contains the least chlorine, namely, platinous chloride. The dry paper is exposed, and then floated upon a hot solution of potassium oxalate to "develop" the print; after washing and drying the operation is complete.

Ferric oxalate has been shown by experiment to be the best iron salt to employ. It is not only more sensitive than

most other iron compounds, but it gives a better quality of image. A little oxalic acid is always used with the ferric oxalate, as a small measure of acidity throughout the whole process is advisable, if not necessary, to secure prints of a rich full colour, to keep the whites clean, and prevent the precipitation of any iron compound on the paper. The platinum compound employed is the potassium platinous chloride ($2\text{KCl}, \text{PtCl}_2$), or it may be called potassium chloroplatinite. The double salt is preferred because platinous chloride itself is not soluble in water, while the double salt is readily soluble, and being easily crystallisable, is purified with facility. It is not impossible to use platinic chloride (PtCl_4), but as the amount of chlorine to be removed from the platinum is twice as much as with the platinous compound, there must be twice as much of the iron salt decomposed by light to give the same amount of metallic platinum. The use of the platinic chloride tends to produce hardness in the print. It is usual to add a little of some oxidising reagent to the mixture of ferrous oxalate and platinum salt just before coating the paper in order to get the vigour that is desirable in the print, and to adjust the range of intensity to the density of negatives that it has become customary to produce. Potassium chlorate is a convenient salt for this purpose; it is similar in effect on the finished result to platinic chloride, but has the advantage of mixing with the solution without giving an insoluble precipitate.

Paper that is coated with the sensitive mixture and dried must be kept dry—not ordinarily dry, but chemically dry—for otherwise, even in the absence of light, it appears that the iron salt is partially reduced by the paper or the matters used to size it, and the effect is a general fog and loss of brilliancy. The sensitive paper must therefore be kept in an artificially dried atmosphere, and this is most conveniently done by storing it in a canister that has a perforated false bottom, below which is anhydrous calcium chloride. It is customary to prepare the calcium chloride by pouring a solution of it over asbestos, then drying and strongly heating the residue. The asbestos being fibrous, the mixture is more coherent, and less liable to allow dust.

to escape from it. It is necessary to periodically heat this mixture to rid it of the moisture that it has absorbed.

The pads used in the printing frame must be dry, and it is advisable to put a piece of indiarubber cloth or other waterproof material immediately behind the prepared paper. Under these circumstances the paper is pressed between two non-hygroscopic and waterproof surfaces if the negative is varnished. And it is very necessary to varnish gelatine negatives used in this process if good results are desired, unless, indeed, the negative is thoroughly dried by heating it immediately before putting the sensitive paper upon it.

When paper prepared as described is exposed to light, the ferric oxalate is decomposed in proportion to the power of the light that gains access to any part into ferrous oxalate and carbonic anhydride, thus—

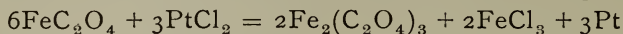


The platinum salt is doubtless changed, but the amount of change is so small that the effect is not visible, and it may practically be neglected. With a little practice it is easy to be as certain of the exposure as in silver printing, because the decomposition of the iron salt is accompanied with a well visible though comparatively slight change of colour.

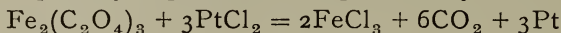
After exposure, the print may be at once developed, or it may be kept for a day or two, observing the same precautions as to dryness as given for the unexposed paper. There are many substances that may be used for developing; even water alone is not without effect, but that which gives the best result in the large majority of cases is a hot solution of the neutral potassium oxalate. This solution is conveniently saturated in the cold with the salt, and development ought to take place in the presence of a little acid, not much, or the print will be hard. The author prefers to very slightly acidulate the developing bath with oxalic acid, and this is the course recommended by Pizzighelli, but obviously, if the paper is prepared with sufficient oxalic acid, the oxalate of potassium bath may be allowed to remain slightly alkaline (as recommended by the Platinotype Company) without doing away with the

acidity of the solution that is in immediate contact with the paper during development.

The development is not an effect analogous to the development of negatives, &c.—it is simply a matter of causing the ferrous oxalate produced to react upon the platinum salt. The simplest expression for the change is—



showing that the ferrous salt takes the chlorine from the platinum, ferric salts and metallic platinum being the result. Pizzighelli and Hubl consider it likely that the ferric oxalate produced as in the above equation reduces a further quantity of platinous salt, presumably thus—



because they have observed a gas to be given off during development, but they do not appear to have tried experimentally whether ferric oxalate will reduce a platinous salt.

Immediately after development the prints are plunged into dilute hydrochloric acid (about one of acid to eighty of water), and they must be changed into a second and third acid bath so long as the slightest appearance of yellowness is imparted to the dilute acid. This is necessary to get rid of the iron compounds. After then washing in plain water for a few minutes, the prints are dried.

Many variations have been proposed in the process as given above, but no variation has yet established itself as an improvement, except, perhaps, in rare cases, and it is very doubtful even then whether a better result would not be obtained if changes in the negative, &c., were made so that the above process would give what is desired.

A weak solution of carbonate of soda or of other alkaline salts, such as sodium phosphate, may be used to develop the prints, instead of potassium oxalate, especially when the prints have been over-exposed, or the paper has a tendency to fog by reason of its having been kept over-long. The action of the sodium carbonate appears to be rather to retard the solution of the iron salts, and so to give them time to reduce the platinum, than to develop the image in the sense that potassium oxalate develops it.

It is advisable not to commit those errors that give the advantage to such salts as those mentioned.

If, instead of using an acid solution of ferric oxalate to coat the paper, a double oxalate of iron and an alkali, such as sodium ferric oxalate, is employed, and the coated paper is not carefully kept dry, the platinum will be more or less reduced during the exposure, and a "printing-out" process may be devised. A print so obtained only requires washing in dilute acid and then water to finish it, the completion of the reduction of the platinum taking place when the washing begins, if it is not already complete. As such a printing-out process, however, depends upon the moisture present in the paper, it is uncertain. The whole surface of the paper may not be equally moist or equally dry. When examining the print, the part exposed may be accidentally breathed upon, or in other ways get moister or drier than the other part, and thus irregularities will occur. It appears also that if the exposure is rapidly done in a good light the reduction of the platinum will not keep pace with the decomposition of the oxalate, and a very marked increase in depth of colour will take place afterwards, while a slow exposure will give ample time for the platinum to get reduced, and no additional vigour will come during the subsequent treatment. In other ways "printing-out" with platinum has been found to fail practically; though it occasionally yields good results it is at the best uncertain.

For putting skies in landscapes, for other combination printing, and for getting variations occasionally desirable, a printing-out process would have advantages. The platino-type process as now practised, however, permits of this sort of work. If a sky is required to be put in so lightly that its details cannot be seen before development, it is only necessary to expose a bit of sensitised silver paper (as in a convenient actinometer) by the side of the print, and a very little experience indeed will enable the operator to get any depth of colour in the finished print that he may desire. The image before development is quite visible enough for a guide in masking what parts are already printed.

A very insignificant proportion of certain salts, such as

mercuric chloride or copper chloride, if introduced into the solution used for coating the paper in the ordinary way, or for printing out, will effect a marked change in the colour of the platinum in the finished print. The Platinotype Company avail themselves of this fact to enable their customers to obtain "sepia" prints; and, for the development of prints on the special paper, they supply a solution, which is acid and contains a ferric salt, to be added to the solution of oxalate used for developing. This addition is made to prevent a degradation of the whites.

In 1888, W. Willis introduced the "cold bath" platinum process, in which the platinum salt is not put upon the paper, but into the solution that is used for developing the prints. The process is therefore quite analogous to Herschel's chrysotype, which has been already described.

In the "cold bath" platinum process the paper is coated with a solution of the ferric salt, and must be carefully kept dry. To produce the best results it must be damped until it loses its crispness shortly before development, either before or after exposure. Without this damping a feeble, grey and granulated image is likely to result.

The developing solution is prepared by dissolving half a pound of a mixture of potassium oxalate with half its weight of mono-potassium orthophosphate in 50 ounces of water, or say—

Potassium oxalate..	..	..	..	100 grammes.
Mono-potassium orthophosphate	..	..	..	50 "
Water to	..	..	..	1,000 c.c.

Three parts of this solution, with two parts of water, are mixed with one part of a solution of 60 grains of potassium chloroplatinite in two ounces of water (or 60 grammes in 1,000 c.c.) when required for use. The final solution therefore has the formula—

Potassium oxalate..	..	..	..	50 grammes.
Mono-potassium orthophosphate	..	..	..	25 "
Potassium chloroplatinite	..	..	..	10 "
Water to	..	..	..	1,000 c.c.

Development is most conveniently done by floating the

exposed paper in the solution for a few seconds, watching the appearance of the image, and refloating if necessary.

When development is complete the paper is immersed in dilute acid, and washed as in the hot bath process.

The cold bath process has very great advantages as a method of getting prints in out-of-the-way places, because of the few materials necessary and their easy portability, especially when citric acid is used instead of hydrochloric acid. It also tends to give purer whites and richer and more transparent shadows. But it does not appear to yield such uniform results, nor so large a proportion of good prints, as the hot bath process. This latter, therefore, still remains the principal method of printing in platinum.

CHAPTER XIX.

PRINTING IN ORGANIC COLOURS.

THERE are very many organic substances that are sensitive to light, but, if we except the indirect use of albumen in ordinary silver printing, the use of organic colouring matters in photography has been very limited.

It must not be supposed that because albumen silver prints owe their colour very largely to albuminous compounds, and are of very uncertain stability, that all organic substances suffer from a like disadvantage. Practically speaking, nothing is known of the composition of the albumen silver compounds, but the substances about to be treated of are of perfectly definite composition, and their reactions have been established by following out the changes that they undergo under varying circumstances. Albumen itself is colourless; it is only when in combination with silver that it becomes coloured by exposure to light, and the coloured product contains silver. But the organic substances considered in this chapter are themselves coloured, or give coloured products without conjunction with silver or any such metal.

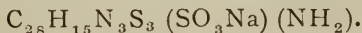
There are many organic substances that are changed in colour by exposure to light. Some light woods darken, the pink colour of certain newspapers fades, and the dyes used in orthochromatic photography are readily bleached. But in these cases it is not practicable to stop the action, and by further exposure a printed image is obliterated.

In 1864, W. Willis, senior, introduced what is known as his "aniline process." It is founded upon the reduction of alkaline bichromates when exposed to light, and the fact that the unreduced chromates give dark coloured products when caused to act upon aniline. A solution of an alkaline bichromate containing a little sulphuric or

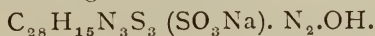
phosphoric acid is applied to the material (paper, silk, &c.) by floating or sponging. After drying it is exposed under a positive and developed by laying it at the bottom of a shallow tray, and putting over it a cover, to the under-side of which two or three thicknesses of bibulous paper have been attached. The bibulous paper is previously sprinkled with a dilute solution of aniline in benzene, turpentine, or ether. The colouring matter which forms the image is a mixture of mauve or aniline purple, with a black tarry substance, which confers considerable permanency upon it. If the bichromate solution used for sensitising is too acid the image will be green, or blue changing to green. Other volatile organic bases than aniline may be used for developing.

The aniline process described above has been employed for the reproduction of engineers' drawings. There does not appear to have been any other practically useful photographic process in which an organic colouring matter plays a fundamental part until a year or two ago. In 1890, Messrs. Green, Cross and Bevan introduced the primuline process. This also gives a positive from a positive, and from the character of the results that it furnishes is likely to prove useful in the production of ornamental designs upon fabrics, as well as upon paper and in gelatine films.

Primuline was first obtained by A. G. Green in 1887. As commercially supplied it is a sodium sulphonate to which the following formula is assigned,



It dyes fabrics, including wool, silk and cotton, of a primrose yellow colour, by merely treating them with its aqueous solution. Paper may be superficially coated by floatation, and the dye may be dissolved with gelatine for the production of films upon glass. By immersing the dyed material in a dilute and strongly acidified solution of sodium nitrite (paper is floated on the solution), the primuline is diazotised *in situ*, being converted into a salt of a base having the formula



This diazo-derivative has the property of forming differently coloured materials when treated with various reagents, and also of being decomposed by light, with evolution of nitrogen. It is only necessary, therefore, to expose the dyed and diazotised surface under a transparency until the light has just destroyed the compound under the clearest parts of the transparency, and then to apply the developer, to get a reproduction of the image of the transparency. The developers used are $\frac{1}{4}$ to $\frac{1}{2}$ per cent. solutions of phenols or amines, the former dissolved with an alkali, and the latter with an acid. β -naphthol gives a red, β -naphthol disulphonic acid a maroon, phenol a yellow, resorcin an orange, and pyrogallol a brown. These are employed in alkaline solutions. Phenylenediamine hydrochloride gives a brown, α -naphthylamine hydrochloride gives a purple, and eikonogen a blue, and these are used in slightly acid solutions.

The products of the destruction of the diazotised derivative by light are yellow, and no method has yet been devised for getting rid of them. Therefore the design of the colour stated above is always produced on a yellow ground. It may be remarked that in processes in which light forms the image, by the destruction of colour or the colour producing material, the effects of over and under exposure are reversed as compared with their effects under the more usual conditions in which light produces the image directly.

In 1889, A. Feer introduced a process in which a solution of a diazo-sulphonate mixed with one or other of the developers mentioned in the previous process, or analogous substances, is caused to impregnate paper, fabric, &c. The diazo-sulphonate is of itself unable to give the characteristic reactions of diazo-bodies, but on exposure to light it is decomposed with liberation of the diazo-derivative, and this at once produces a characteristic colour with the other substance. The image is thus printed out directly from a negative, and the unaltered sensitive mixture is washed out in water or very dilute hydrochloric acid.

CHAPTER XX.

CHROMATED GELATINE.

BY far the greater number of methods of printing from photographic negatives are based upon the changes produced by light in a mixture of bichromate of potash or ammonia with gelatine or some organic substance that behaves in a similar way.

Mongo Ponton, in 1839, showed that paper dipped into a solution of bichromate of potash, and dried, would furnish a negative photograph if exposed to light beneath a drawing. A faint yellowish brown tint was produced where the light had acted, and the changed chromium compound (chromate of chromium) was insoluble in water, while the unchanged chromate might readily be washed away.

If a film is made of a mixture of gelatine and bichromate of potash, and is then exposed to the light, it will be found that where the light has acted the gelatine has been made insoluble, or less soluble in hot water and in certain solutions that dissolve unchanged gelatine. In 1852, Fox Talbot patented a method of coating steel plates with such a film, exposing it beneath a negative, and washing it. He says that thus not only is the unchanged chromate removed, but the greater part of the gelatine is washed away from those parts not affected by the exposure to light. Talbot then proceeded to etch the plate with platinum chloride, the gelatine adhering to the plate resisting the action of the etching solution in proportion to its exposure. It has been stated that Talbot's image in gelatine differed from a "carbon print" only in having no pigment in it. It was, however, as totally different from a carbon print as two results produced by the same reagents can be, and this will be obvious on a little consideration when we come to treat of "pigment printing."

When a film of chromated gelatine is exposed to light

under a negative and then put into cold water, it will be observed that those parts acted on by light (which are less soluble in warm water) absorb water less freely than the unchanged gelatine, and also swell up to a less extent. It is, therefore, possible to get the design in relief by the mere soaking in water. But in proportion as the changed gelatine refuses to absorb water, so will it "take" a greasy ink such as is used in ordinary letterpress or lithographic printing processes. By applying such an ink with proper precautions it is possible to get impressions in greasy ink after the manner of ordinary lithographic methods. Paul Pretsch, in 1854, patented these uses of chromated gelatine.

A. L. Poitevin, in 1855, obtained protection for mixing pigments with chromated gelatine, exposing under the negative, washing away the gelatine that remained soluble, and getting a "pigment print," or, as it is less advisedly called, a "carbon print."

These are only the very beginnings of the applications of chromium compounds mixed with organic matter to the purposes of photographic printing. It will be seen that any reagent or circumstance that affects the solubility of gelatine, or that causes it to swell or to shrink in bulk, are important; and to these may be added those procedures that are found to break up the surface of gelatine or cause "reticulation," because when a smooth surface is desired such an effect is to be avoided, but in certain photo-mechanical processes, reticulation is purposely brought about to get a surface that will the better hold the ink.

The following details are chiefly derived from J. M. Eder's classical essay on the reactions of chromates on organic bodies, and many of the statements are quoted *verbatim* from a somewhat condensed account of it that was published in the "Photographic News."

Gelatine dissolves in acetic acid as easily as gum in water, so that carbon prints can be developed by the cold acid. Weak hydrochloric, sulphuric and oxalic acids have the same effect; added in very small quantities to the water they will dissolve out the gelatine without decomposing it. Hot water will develop carbon prints more quickly and with a more refined effect, but plates for photo-

mechanical printing are better developed by acetic acid, because warm water penetrates and softens the exposed gelatine, and thus causes unequal swelling and contraction.

The carbonates of potassium and sodium and sulphate of magnesium confer fluidity upon a concentrated solution of gelatine. Weak solutions of soda and potash dissolve and decompose gelatine slowly in the cold, much more quickly when heated. Ammonia acts only as a weak solvent.

Very small quantities of carbolic acid are useful in gelatine to prevent putrefaction, but larger quantities precipitate the gelatine. But carbolic acid will not prevent a film of chromated gelatine from getting insoluble even in the dark, as this is due to the spontaneous decomposition of the chromium compound. Salicylic acid is also a useful antiseptic, and gelatine films containing it dry more quickly than the pure jelly.

A weak solution of chromic acid precipitates gelatine, and the precipitate melts when heated. But if the gelatine treated with chromic acid is dried, even in the dark, it becomes insoluble, while gelatine treated with the chromates and dried in the dark remains soluble. Hence a crude bichromate of potash containing free chromic acid is to be avoided.

Gelatine, with bichromate of potash not in excess, dries to a transparent layer without any signs of crystallisation, but too much of the salt will cause crystallisation, and so give a useless film. A good gelatine that can take up five to ten times its weight of water may be mixed with three to four times its own weight of the bichromate without getting crystallisation on drying; but an inferior gelatine that takes up only three to six times its weight of water will stand only twice its weight of the bichromate. But one-third to one-fourth more of ammonium bichromate may be added than of the potassium salt. If the drying of the films or coated glasses is done at a high temperature, 40°C . to 50°C ., nearly double the amount of the potassium compound may be added, and a still larger proportion of the chromate may be used if the film is to be dried upon paper.

By heating a mixture of gelatine and bichromate of potassium to the boiling temperature for sometimes so short a time as fifteen minutes will render the cooled, solidified gelatine insoluble in hot water, and in general the treatment of gelatine with the bichromate, as in sensitising carbon tissue, raises the temperature at which it will dissolve in water some two to five degrees Centigrade. Rapid drying at a low temperature tends to avoid insolubility.

Chromated gelatine films, if kept dry and in a dry atmosphere, as in a box with a desiccating agent, may be kept in a soluble state for a long time, but if kept in a moist atmosphere they soon become insoluble. An atmosphere saturated with moisture will cause sensitised carbon tissue to become quite insoluble in a week.

Concerning the reticulation of gelatine films, increase of the bichromate tends to produce grain. A certain temperature in drying may give a grain, while a higher or lower temperature would give a smooth surface. Some substances that tend to keep gelatine liquid, as acetic acid and calcium chloride, tend to produce a grain, even in drying at a low temperature. Thick films and concentrated solutions of gelatine give a coarse, rough grain. If two plates are dried at the same temperature, the one to which the air has better access will have the coarser grain.

Air-dried gelatine films contain about 17 per cent. of water. Sensitised films are more sensitive when kept over water, and less sensitive when kept in an artificially dried atmosphere, but as stated before the moist condition is conducive to insolubility. Hence to preserve a sensitised film it should be kept in a chemically dried atmosphere, and to regain sensitiveness it may be placed in a moist atmosphere until flaccid shortly before being required for use.

Concerning collotype plates, which have sensitised gelatine films exposed and soaked in water, dilute nitric acid (1—6) lowers the relief, and promotes the appearance of the most delicate tones. The following substances increase the power of the films to take up ink:—Alkaline dichromates, alum, the soluble chlorides, dilute hydro-

chloric, sulphuric and nitric acids. Potash, borax, and potassium cyanide tend to clear the plate. Acetate and hyposulphite of sodium, and the chlorides of calcium, zinc, and sodium keep the films moist after printing, without making them sticky or letting them decompose. Collotype plates dipped in a six per cent. solution of zinc chloride, become harder, and are able to furnish a greater number of impressions.

If the yellow potassium chromate (K_2CrO_4) is used for sensitising carbon tissue, it will require an exposure of twenty to fifty times the length necessary when the dichromate is used. But the monochromate of ammonium does not show this lack of sensitiveness, probably because the ammonia is volatile, or because it is decomposable. Hence ammonia may be added to the bichromate of potash without loss of sensitiveness, and films prepared with the mixture retain their sensitiveness for a longer time.

As to the actual chemical change produced by light in a mixture of bichromate of potassium and gelatine, Dr. Eder concludes from his experiments that a chromate of chromium is formed, and that the gelatine associated with this compound in the part insoluble in water after the exposure is not changed in its chemical composition. The organic matter, therefore, that is oxidised at the expense of the chromium salt appears to remain soluble in water, and to be washed away.

CHAPTER XXI.

PIGMENT PRINTING (CARBON PRINTING).

WE have seen in the last chapter how that Poitevin in 1855 sought to get photographic prints in pigments by mixing the pigments with chromated gelatine or its equivalent, exposing a film prepared with the mixture under a negative, and then washing away the parts remaining soluble. The gelatine where made insoluble by the light would retain the pigment. This process, however, could not give half-tones, because, as the insolubility of the film starts from its outer surface, in all those parts except where the action of the light thoroughly penetrates the film there will be a layer of soluble gelatine, &c., underlying the insoluble part. All, therefore, except the deepest shadows, are loosened on development from the supporting paper, and washed away.

It was in 1858 that J. C. Burnett pointed out this fault, and that it might be remedied by exposing the sensitive film through its support—printing, that is, on the back instead of the front of the coated paper. The Abbé Laborde in the same year, and Blair, of Perth, in the following year, both made the same suggestion, and, as a matter of fact, good pigment prints were produced in 1858.

A. Fargier, in 1861, did away with the awkwardness of exposing the back instead of the front of the sensitive material, by forming his film of sensitised and pigmented gelatine upon glass, exposing the face of it under the negative, coating the exposed film with collodion, and then developing in hot water. As that part of the film in contact with the glass remained soluble, the film left the glass when development began, but it was held together by the coating of collodion, and when completely developed, it was caught upon a sheet of paper coated with gelatine,

the paper taking exactly the place that the glass plate had occupied originally. The mounted picture thus produced had the collodion film still on its face, but this was removed by a mixture of alcohol and ether.

Although the necessities of pigment printing are recognised and provided for in these inventions, the methods proposed do not include a process that could be practically adopted for the commercial production of photographs. In 1864 J. W. Swan obtained protection for a process of carbon printing which was afterwards worked on a large scale by A. Braun & Co., and which furnished results of such a quality that they have never been surpassed. Swan spread his pigmented and sensitised gelatine upon paper, and so prepared what is now called "carbon tissue," or pigmented tissue. This was exposed under the negative in the usual manner, and then the procedure varied according to whether the finished picture might be inverted or whether it had to be non-inverted. The production of an inverted picture is the simplest, and the modern method working on the same principle is called "single transfer," because the exposed film is transferred only once. To effect this, Swan cemented the exposed tissue face downwards upon the surface where the picture was to remain by means of a layer of albumen. It was then developed with warm water, the paper that formed the original support of the gelatinous film readily skinning off when the soluble gelatine began to soften. But when a non-inverted picture was required the development took place upon a "temporary support," and the picture was afterwards transferred to its final support. This process is called in modern language "double transfer" for obvious reasons. Swan's method of double transfer was to expose the tissue as before, and to cement it face downwards upon paper by means of a solution of indiarubber in benzene. Development was performed upon this temporary support, and then the paper that was to permanently carry the picture, having been previously coated with gelatine made almost insoluble by means of alum, was well wetted and forced into contact with the print. When dry the temporary support, still cemented by the indiarubber to the face of

the picture, was removed by moistening it with benzene to soften the indiarubber.

With these methods, carbon printing became a practical fact. There have been only two other improvements in matters of detail that are important enough for notice here, namely, the doing away with the indiarubber to cement the exposed print to its temporary support by J. R. Johnson in 1869, and the preparation of a flexible temporary support by J. R. Sawyer in 1874. Johnson showed that a surface impervious to water would hold the film during development if merely squeegeed upon it, without the use of any cement. Sawyer's support is prepared by coating paper with gelatine mixed with chrome alum, so that the layer when dry is insoluble, and this film is treated with an alkaline aqueous solution of lac. When dry, the surface is subjected to great pressure between polished plates.

The pigmented paper used in printing by this process is manufactured by coating paper with a solution of gelatine and sugar mixed with the desired pigment. Soap is sometimes used instead of, or in addition to, the sugar. It appears that these last ingredients give a greater possibility of sensitiveness, besides keeping the film from getting too hard and brittle. The coating is generally done by means of machinery.

The permanency of the finished print depends upon the nature of the pigment employed, and although a considerable assortment of colours is available as having no injurious effect upon the gelatine or the bichromate, it is not always easy to get just the tint desired. Commercially, it is necessary to prepare tissues giving the "photographic brown" and "photographic purple," merely because it has become fashionable to have photographs of such colours. Indeed, many ignorant people do not consider that they have a proper photograph unless it resembles an albumen silver print. The cochineal lakes lend themselves readily to the preparation of such tints, and they were at first used for that purpose. But as cochineal colours are fugitive, pigment prints containing them as an ingredient gradually change colour. Alizarine lake is now universally employed

instead, as it is far more permanent. But if a simple unchangeable pigment is used, such as carbon (lamp black, bone black, Indian ink, etc.) or oxide of iron (Venetian red), then the finished print is unchangeable. Whatever pigments are employed, it is necessary to avoid any colouring matter that would react with the gelatine to make it insoluble, or that would be injuriously affected by hot water or weak alum solution. The colour should be finely ground, and the gelatine mixture must be very carefully made uniform. If the coated paper is kept for a short time in a horizontal position before the gelatine has set, the coarser particles of the pigment settle down more or less; and there is advantage in this, because the upper surface of the gelatine, which gives the details in the lights, has the finer pigment, and is therefore more delicate, while the shadows showing the coarser particles have, perhaps, a slight appearance of granulation that tends to give them transparency.

The sensitising of the tissue may be done during its manufacture or afterwards. The most uniform and economical method is to add the bichromate to the gelatine mixture before coating. Tissue so prepared will keep in good condition for two weeks perhaps, with common care, as, for instance, putting it under a weight that it may be pressed together to exclude air as much as possible, and not allowing it to remain in a room where the air is vitiated by respiration and combustion, and especially not near the ceiling of any inhabited room. But with extra precautions the sensitised tissue may be kept for much longer, as stated in the previous chapter. The deterioration of tissue is due to its becoming insoluble in warm water. Therefore, whatever the age of sensitised tissue, it can easily be discovered whether it is fit for use by putting a fragment of it into warm water. If the gelatine dissolves off it is all right, but if water as hot as the hand can bear does not affect it, it is useless.

Tissue prepared in the unsensitised condition will keep almost indefinitely. To sensitise it, it is soaked generally for about three minutes in a three to four per cent. solution of bichromate of potassium. Unless the salt is specially

prepared to be free from excess of acid, four or five minims of strong ammonia is added to each ounce of the solid bichromate of potassium taken.

There are other methods of sensitising. The paper may be floated on the solution, or a stronger solution may be applied by a sponge to the back of the tissue after laying it face downwards on a suitable surface. This last method is due to H. J. Burton, who gives the following formula for the solution :—

Water	20 ounces.
Liquor ammonia	1 ounce.
Bichromate of potash	4 ounces.

Burton says :—“ Have a flat board larger than the sheet of tissue to be sensitised, and cover it with blotting-paper, and on that lay the tissue face downwards, first dusting it and the tissue with a flat camel-hair brush. Now pour a small quantity of the sensitising solution into a saucer, and with a sponge of good size wet the back of the tissue evenly with the solution for, say, three minutes, and hang up to dry in a room where there is a fire, but taking care to let the back of the tissue be presented to the fire, and at a distance of about six feet from it.”

However the tissue is sensitised, it should not be more than a few hours (eight to twelve perhaps) in drying. It must be dried in a room free from noxious fumes, and obviously the apartment should have only very subdued light, if any, gaining access to it. The tissue cannot be warmed to dry it as gelatine plates are, because of the easy solubility of the coating. Indeed, in hot weather, if the sensitising solution is above 65° Fahr., it should be cooled to below this temperature by putting ice into it to avoid incipient solution of the gelatine.

Negatives for pigment printing should have a border of black varnish an eighth or a quarter of an inch wide, preferably on the glass side. An opaque layer of varnish is not necessary or desirable. This gives the exposed tissue a border of soluble or partially soluble gelatine which adheres more firmly than insoluble gelatine would to the surface it is transferred to, and so tends to prevent the film “ washing up ” or leaving the surface it should adhere

to during development. The tissue is not in the best condition for exposure when it is as dry as possible. It must be dry to the touch, of course, and so dry that it will not stick to the negative, but it should not be horny. If it is horny it will be advantageous to keep it in a damp place until it just becomes limp. In this condition it is more sensitive and more easily manipulated.

The effect of exposure is invisible, and therefore an actinometer must be exposed simultaneously as a guide to the activity of the light. Old tissue is more sensitive than new, because with age, up to the production of actual insolubility, the tissue approaches that condition, and requires a less light effect to induce it. It is advantageous to use tissue that has been sensitised two or three days previously.

Unless sensitised tissue is kept absolutely dry—a condition that can only be approached even by close vessels and desiccating reagents—it gradually (spontaneously, as it is called) becomes insoluble. Light produces insolubility with comparative rapidity, and after light has initiated the more rapid change the change will proceed after the light is withdrawn, not so quickly as if the action of light were continued, but much more quickly than if the tissue had not been exposed to light at all. This is called the “continuing action” of light, and was first observed by Captain Abney. It is necessary on this account to be very much more careful to exclude light from tissue that is to be stored than would appear to be necessary by comparing its sensitiveness with that of sensitised silver paper. The continuing action of light must be allowed for when development does not follow within an hour or two of exposure. When the light is poor, or many prints are wanted from one negative, the prints may be only one-half or even a quarter exposed, and if kept in a dark place for a sufficient time before development the under-exposure will be compensated for. This method of printing has been practically carried out on the large scale, but it is rather uncertain, and apparently not much patronised by commercial carbon printers. From twelve to eighteen hours will probably double the effect of exposure, and from sixteen to forty-two

hours will increase exposure effect about eight times; but very much depends upon the condition of the tissue. If kept scrupulously dry the continuing effect of light is almost arrested. A print produced by keeping after a short exposure tends to be harder than one fully exposed, and Captain Abney has shown that a thin negative of a black and white subject will give the same effect as a very dense one when chromated gelatine is exposed under it if a very short exposure is given—just sufficient to start the action through the transparent parts of the negative only—and then the effect is allowed to continue in the dark. While the thorough desiccation of the tissue arrests this continuing action, it is only a certain measure of dampness that enables it to proceed. Tissue that is wet scarcely shows the phenomenon, and is in general very lacking in sensitiveness. For this reason the development of pigment prints may be carried out in ordinary daylight without detriment to them. This continuing action is not exceptional, it is shown in even a more marked way by chloride of gold; and, on the other hand, it is not the rule, for paper soaked in a solution of a uranium salt gives a vigorous image after exposure if treated with red prussiate of potash, but the effect of exposure is very markedly lessened by keeping the paper for an hour or two, and eventually dies away.

For development, a pigment print must be “mounted” either on its final support, as in single transfer, or on a temporary support, as in double transfer. The final support for the single transfer process consists of fine white paper coated on one side with gelatine made insoluble. To mount the exposed tissue upon it, they are both plunged into cold water, and as soon as the tissue uncurls (it rolls up more or less when put into water) and is nearly flat, it is drawn out of the water with its face against the face of the transfer paper, and the two are placed upon a flat board which is conveniently covered with zinc. The back of the tissue being uppermost, the squeegee is applied gently at first until a fair amount of adhesion is secured between the two papers, and then the squeegee is used with more vigour than a novice is apt to

consider necessary. The mounted print is allowed to remain twenty minutes or so before development, and it is convenient when many prints are being treated to place them as they are mounted in a pile with blotting boards between them. The pile is then turned over, and the prints are in correct order for the next operation.

To develop, the mounted prints are plunged into water at a temperature of 105° to 110° Fahr., and almost immediately the two papers are separated by gently but firmly peeling off the paper that supported the film during exposure. This paper is thrown away. The greater part of the film remains upon the transfer paper, and to wash away the gelatine that still remains soluble, the print is laid upon the top of the water and the water of the bath is dashed over it with the hand. The process of development may take two or three minutes, but may be prolonged to an hour or two of soaking in cases of over-exposure, and at the same time hotter water may be used. If any part of the print is too dark, a jet of hot water from an india-rubber tube or from a kettle may be applied. A print that is under-exposed may be developed in cooler water, and there is thus room for the exercise of skill in producing just that quality of print that the artist may desire.

When development is complete, the print is plunged into cold water, and left there a few minutes or until it is convenient to proceed with it. It is then passed on to an alum solution, containing 4 to 5 per cent. of the salt, and after soaking until all trace of yellow colour has disappeared from the print, back or front, it is washed and hung up to dry.

The tanks used for these processes may conveniently be of zinc for cold water, and of tin when heating is necessary, but as the alum solution would corrode these metals, it is used in an earthenware or leaden vessel.

In a picture produced by single transfer from an ordinary negative, the object is shown as if it were viewed in a looking glass—the picture is “reversed.” To get a non-reversed picture, it is necessary to get another reversal, which shall turn the picture round a second time, so to speak, and bring it back to its proper relationship to the object.

This second reversal can be done in two ways. If many prints are wanted, it is certainly better to effect the change once for all by making a reversed negative; while, if only a few prints are to be made, it will generally be more economical to reverse each print as in the method technically called "double transfer." In printing by double transfer, the exposed tissue is mounted on a temporary support, and transferred from this to its final support.

Although these transferrings are not difficult to effect now that the process of carbon printing has attained to so great a degree of perfection, there is at each transferring a tendency to lose some of the most delicate parts of the picture; and therefore the method of single transfer is always to be preferred when perfection in the finished result is the only aim of the printer. One perhaps gets nearer to a perfect transferring by coating the exposed tissue with collodion before laying it down upon its support for development, but the degrees of perfection attainable by these variations are so little removed from one another that even an acute observer, if unacquainted with the technicalities of the process, would probably be unable to find any superiority in the prints done by the more theoretically perfect methods.

As a temporary support, sheet zinc polished or grained, glass polished or finely ground, may be used, and opal glass is to be recommended as showing the details of the picture more clearly during development. But the temporary support that is most convenient is that prepared according to J. R. Sawyer's patent as above described. Whatever support is used it must be waxed before mounting the print upon it, so that it may yield up the print when desired. The waxing composition recommended by the Autotype Company is—

Yellow resin	..	..	..	6 drams.
Pure beeswax	..	..	..	2 drams.
Turpentine ..	..	..	..	1 pint.

A little of this is applied to the surface of the temporary support, and spread over it with a piece of cotton flannel. After a few minutes it is lightly polished with a clean rubber, and in a few hours the support is ready for use.

After developing and soaking in alum to get rid of the chromium salt and washing, the print may be transferred to its final support at once, but it is better to let it dry first. Paper prepared to receive the picture from the temporary support is coated with hard gelatine mixed with a white pigment. This gelatine must be nearly insoluble but not quite, and the most convenient method of securing the proper condition is to prepare the support without affecting the solubility of the gelatine, and to soak it for half-an-hour or so in a two per cent. solution of alum just before required. This is the method now adopted by the Autotype Company. The print on its temporary support and the prepared final support are put into water at about 70° Fahr., squeegeed together, and hung up to dry. When dry the temporary support will readily leave the print.

It is obvious that carbon prints may be transferred to almost any desired surface, if only it is suitably prepared to receive it. In the Autotype Manual* will be found many applications of carbon printing with full practical details.

There is another method of pigment printing capable of giving very fine results, though it is but little practised at the present day. It is generally known as the "powder" or "dusting on" process, because the pigment is taken in the form of a fine powder, and is dusted on. In this process advantage is taken of the fact that certain sticky substances, such as honey and glucose, lose their stickiness when mixed with potassium or ammonium dichromate and exposed to light. Moreover, as the loss of stickiness is proportional to the light that has gained access to the surface, if such a film is exposed beneath a transparency and a pigment in fine powder is then lightly brushed over it, the colour will adhere in greatest quantity at those parts that have not been affected by the light, and if proper care is taken it will not adhere at all to those parts subjected to the maximum of light effect, and the result will be an excellent reproduction of the *cliché*. If a positive picture is required a positive transparency must be used; if a negative is employed the result is a negative.

*Published by the Autotype Company.

J. Obernetter, of Munich, at one time used this process regularly for the reproduction of negatives. His formula and practice will serve to illustrate the general method, though very considerable variations in the sensitive mixture have been made from time to time. Obernetter's formula was—

Dextrine	..	..	..	4 grains
White sugar	..	..	..	5 "
Bichromate of ammonium	..	..	..	2 "
Water	..	..	..	100 "
Glycerine	..	..	..	2 to 8 drops

The mixture is filtered, and the glass plate is coated with it after the manner of coating with collodion, and then dried in a horizontal position at a temperature of from 120° to 170° Fahr. In five or ten minutes the film is dry, and while still warm it is exposed under the negative to be reproduced for from five to fifteen minutes. A slight change of colour is evident where the light has acted. The plate is then made a little warmer than the air where development is to be performed; it is laid upon white paper, and very finely powdered graphite is gently brushed over its surface by means of a soft brush. Blowing or breathing upon the plate increases the ease with which the powder adheres. The amount of glycerine used in the mixture makes the film suitable for varying conditions of the air; it should be decreased or even omitted in a moist warm atmosphere and increased in winter. When development is complete the film is coated with a plain collodion containing eight to ten grains of pyroxyline to the ounce, and is then cut round with a sharp knife. The plate bearing the film is then put into water, and soon the compound film leaves the glass because of the solubility of the under layer of the film. It is at once turned over and brought out upon the plate. If the film were not turned over the result would be a reversed negative. A thin solution of gum is poured over the film, and when this is dry it is varnished.

CHAPTER XXII.

WOODBURYTYPE.

THOSE methods of printing in which the direct action of light is necessary for the production of each individual proof are considered photographic processes, but when by the action of light a printing surface is obtained that will furnish proofs mechanically—that is, without any further need for light—the process is termed photo-mechanical.

In pigment or carbon printing, as described in the last chapter, the picture consists of a layer of pigmented gelatine of thickness varying according to the transparency of the negative; it is, in short, a low gelatine relief, but as the gelatine is pigmented and the relief is very low, its appearance when dry is simply that of a surface covered with the varying intensities of colour as desirable to form the picture. Instead of getting this varying thickness of pigmented gelatine by exposing the sensitised film to light and developing, it may be obtained by *casting* coloured gelatine in a suitable mould. This obviously is a photo-mechanical process, and as we owe it to the inventive genius of W. B. Woodbury, it is called Woodburytype.

By taking advantage of the insolubility of sensitised gelatine when exposed to light, and the fact that the insolubility will penetrate to a greater depth the longer the light acts or the more powerful the light may be it is possible to get a relief picture from any negative where the light and shade of the original are represented by a proportional amount of relief, the darkest part of the original being represented in highest relief. This gelatine relief, when dry, can be made to give an intaglio or sunk image in a soft metal by simple pressure, or by using an easily fusible substance a cast of it may be taken.

The intaglio in metal may be made to reproduce any number of coloured gelatine reliefs by pouring the melted gelatinous mixture upon it, and pressing the flat surface that is to receive the relief into contact with the mould until the gelatine is set. The thickness of the layer of coloured gelatine determines the amount of colour, and as the colours used are more or less transparent, the thicker the layer of colour is the deeper is the tint. The final pigmented gelatine relief, when dry, exhibits so small an amount of relief as to be scarcely noticeable, especially when finished in the ordinary way. A Woodburytype print is, therefore, a pigmented gelatine relief in which the thickness of the relief determines the amount of colour, and therefore the depths of tone of any part of the print.

In this process it is difficult to get a white part of any appreciable extent unstained; while in carbon printing there is no analogous difficulty, because the gelatine that remains soluble after the exposure is dissolved and washed away. In the first case the process is mechanical, and every print from the metal relief is alike if proper care is taken; but in the second process very considerable variations may be made according to the taste and skill of the printer, because the solubility of the exposed gelatine film is a comparative matter depending upon the temperature of the water used, and the time it is allowed to act.

As a single transfer carbon print, and also a Woodburytype print is a relief picture, it might be considered that if a mould were made from such a print, reproductions might be multiplied from such a mould. But this is obviously impossible when one remembers that such a mould would be made from a dry gelatine relief, while it is a bulky solution of gelatine that fills the mould in the printing operation. It is necessary, therefore, to prepare a relief which, when dry, is in as high relief as the bulky pigmented solution of gelatine is required to be to get the necessary contrast in the picture.

The analogy between a Woodburytype print and a single transfer carbon print leads to the same result as far as the reversing of the picture is concerned, and if a non-reversed print is desired, a reversed negative must be

employed. It is possible to cure the reversal in Woodbury-type by placing the back of the gelatine relief against the metal that is to furnish the mould, but this is not a desirable procedure.

The gelatine relief is prepared by means of a film of sensitised gelatine considerably thicker than is used as carbon tissue, and containing very little, if any, pigment. The exposure under the negative must be rather longer than in carbon printing, and there is an advantage in exposing to the direct rays of the sun as the light is then less scattered in the film. The development is much the same as in carbon printing, but very much more prolonged, and the temperature of the water is considerably raised towards the end. The developing may extend over from two hours to as many days. The relief is hardened with alum, washed and dried.

From this relief a metal mould is prepared, and in the original process, as patented by Woodbury in 1864 and perfected during that and the following year, the gelatine relief is pressed into a lead plate. A hydraulic press is necessary for this operation.

Since then Woodbury has modified the production of the metal mould, dispensing with the hydraulic press. The earliest "stannotype" process consists in supporting the gelatine relief upon a true surface, as of plate-glass, covering it with tinfoil, and passing them together through a rolling press with indiarubber rollers until the tinfoil is pressed into the relief so perfectly as to be a counterpart of it. The tinfoil is then strengthened by electro depositing copper upon it, and then a glass plate, coated with a suitable resinous cement, is pressed into contact with the copper. The required metal mould is thus made in tinfoil, and then strengthened sufficiently for printing from.

The more recent and more generally available stannotype process utilises a gelatine mould, the mould being coated with tinfoil to preserve it. For this method a gelatine intaglio, instead of a relief, is necessary, and this is prepared by exposing a sensitised gelatine film, and developing it as for the relief, but the *cliché* employed must be a transparency instead of a negative. Before putting the

tinfoil upon the surface of the mould, it is covered with a thin solution of indiarubber in benzene, which serves to cement the coating of metal to the gelatine.

The gelatine reliefs prepared as above can be put to other uses than the production of moulds for printing from. One of the simplest of these applications consists in merely placing a piece of paper against the relief, and passing them together through a suitable press. The paper is made transparent in proportion to the pressure it is subjected to, and as the highest part of the relief causes the greatest pressure, a sort of water-mark effect results. This is the "photo-filigrane" process.

In these methods of Woodbury a perfect gradation of tint may be produced—a result which is practically impossible by any other photo-mechanical process.

CHAPTER XXIII.

COLLOTYPE (PHOTO-LITHOGRAPHY, PHOTO-ZINCOGRAPHY).

IT has already been stated that when light acts upon chromated gelatine it lessens its capacity for absorbing water, and at the same time proportionately enables it to receive greasy matter, such as printers' ink. It is this discriminating power of the prepared lithographer's stone bearing its transfer that makes lithographic printing possible, and a gelatine film exposed under a negative may be printed from after the manner of lithographic printing. All processes in which a gelatine film is utilised in this way are included in the general term—collotype. In the early days of collotype printing it was sometimes called photo-lithography, but that term is now very properly restricted to processes in which a photograph is transferred to stone, and then printed from.

It appears that we owe the idea of "inking up" an exposed chromated gelatine film to Poitevin. In 1865, C. M. Tessie du Motay and C. R. Maréchal secured a patent in connection with collotype printing, the chief points appearing to be certain methods of hardening the gelatine film, and so endeavouring to make practicable what was before only a theoretically possible process. But Tessie du Motay could get only perhaps fifty to one hundred impressions from one film before it became unusable.

"In 1867 an invention was patented in Berlin by Messrs. Ohm and Grossman" (quoted from J. R. Sawyer), and in October, 1869, an English patent was granted for the same. This invention refers to the very important matter of giving the glass plate that is to bear the collotype film a preliminary coating of an aqueous solution of albumen, gelatine and bichromate, drying this and exposing it through the glass to light until it is made insoluble.

But early in 1869, if not in 1868, Albert, of Munich, appears to have used a similar substratum, and to have very successfully produced large numbers of impressions—over a thousand from one plate.

Until the last few years, collotype printing was almost entirely in the hands of the Autotype Company so far as this country is concerned. The following details concerning the process as practised by them are taken from J. R. Sawyer's own description. A glass plate is warmed to 100° Fahr., and is coated with an aqueous solution of a mixture of albumen, gelatine, and bichromate of potassium, and is then kept warm until dry. This first coating is caused, not only to cover the surface of the plate, but to flow over each of its edges to secure it more firmly to the glass. The mixture for the second coating consists of an aqueous solution of gelatine, with a little albumen and the bichromate, to which, when thoroughly mixed, a small quantity of an alcoholic solution of certain gums is added, together with a little nitrate of silver and an alkaline iodide. The gum and the silver iodide are precipitated in a very fine condition. This mixture is applied to the plate in the same manner as the first, after the plate has been exposed to light, allowing the light to reach the film through the glass, and has been washed in warm water. In two or three hours, when the second coating is dry, the plate is exposed under a reversed negative; it is then well washed with cold water, and allowed to dry spontaneously. The plate is then ready for printing from.

Instead of the substratum given above, Husnik has substituted an aqueous solution of albumen and sodium or potassium silicate (water glass).

There are very many modifications in the manner of preparing collotype plates. It is not necessary to mix any substance with the sensitised layer, as is done in Sawyer's method, because the gelatine surface will become of itself reticulated and able to hold the ink. If proper care is taken the reticulation is very fine, so that the want of continuity in the ink on the proof is scarcely visible without the aid of a microscope. A coarsely grained plate is, however, more easily printed from.

It requires considerable skill to ink up a collotype plate—a skill analogous to that of the lithographer, though with modifications. The presses used at first were of the ordinary lithographic pattern, in which pressure is got by drawing the plate with the paper on it under a fixed “scraper.” This principle, however, is not advantageous; a rolling pressure is better, but a direct vertical pressure is generally preferred, at least for small work. Steam presses are now largely used in Germany, which turn out prints very much more rapidly than is possible by hand.

Instead of preparing a gelatine film so that it shall be able to resist the wear and tear of printing from, it may be so prepared as to furnish only a very few prints. If only one perfect print is obtained in lithographic transfer ink, the ink of the print may be transferred to a lithographic stone, and will then furnish proofs by ordinary lithographic printing. Such a procedure is termed “photo-lithography,” and the print obtained from the gelatine film is called a “transfer.”

To prepare a transfer, a thin paper is floated on a solution of gelatine mixed with a dichromate, or the paper may be coated with gelatine first, and then sensitised, as in carbon printing. The negatives for this process must have no half-tones, and the opaque parts are better if they are what is called quite opaque, while the transparent parts are not fogged at all. After exposure beneath such a negative the film is covered with a thin layer of ink by any suitable means, and then floated on or soaked in water. The water swells the gelatine that has not been affected by light, and, by means of warmer water and gentle friction with a sponge or a soft brush, the ink is removed, except from the insoluble parts of the gelatine.

Instead of covering the exposed gelatine film with ink and then removing those parts that do not form the required print, the exposed film may be soaked in cold water, then blotted off, and inked with a velvet roller. In this case, only those parts of the film that have been acted upon by light take the ink. The use of the velvet roller is due to F. Butter, of Woolwich Arsenal.

Instead of transferring the print to stone, it may be transferred to a prepared zinc plate, and then printed from. This is photo-zincography.

CHAPTER XXIV.

OTHER PHOTO-MECHANICAL PROCESSES.

IN reviewing the printing processes already considered it will be observed that we have passed gradually from true photographic processes to photo-mechanical processes, and in doing so we have been gradually passing away from our immediate subject. Therefore, although we have approached matters that well deserve a larger space devoted to them than any of the strictly photographic methods, we have treated them in a more summary way. This present chapter deals with by far the most important item of all, and one which could not be done justice to if the whole of this treatise were devoted to its consideration, but the purpose of this work will be served by a mere reference to principles.

In strictly photographic processes of printing the range of colour intensity desired in representations of natural objects is perfectly rendered, and this result is also realised in the Woodburytype processes. Collotype printing appears to the cursory observer to render half-tones, but it does not do this in the strict sense of the term. The reticulation of the gelatine surface gives a want of continuity in the tints of the print. It is a mechanical imitation of half-tone, though produced spontaneously. In describing the process of photo-lithography it was mentioned that half-tone negatives were not available—the negative must be “black and white” only. This also applies to the other photo-mechanical processes.

But as it is necessary to produce prints from half-tone negatives by mechanical processes many methods have been devised of “breaking up” the tones of a negative so that the half-tones shall be imitated, as they cannot be reproduced, in ways similar to the imitation of half-tones in engraved plates and typographic blocks. In these cases the

print consists of lines or dots or both, and the lines and dots are thicker or nearer together where a dark tone is to be represented than for a lighter tone. Although the ink is uniformly opaque, or nearly so, a semblance of half-tone is realised by varying the proportions of inked and uninked surface. It is important that the lines or dots be so fine as not to be distinguishable as such at the proper distance from which the print is to be viewed.

The need for breaking up the tints of ordinary half-tone negatives to enable them to furnish prints by the mechanical processes has led to many inventions for the purpose. Some of these produce theoretically the desired result, while others give what is wanted apparently by accident.

The grain or stipple may be obtained by the reticulation of gelatine as in a collotype plate, or by photographing the half-tone subject through a network or through one or more lined transparent screens, or the plate on which the grained negative is to be taken may have a preliminary exposure to light through a fine network. By means of powders dusted over or allowed to fall upon or incorporated with a surface that is to furnish a printing surface, a grain may be produced. A plaster cast from a gelatine relief may be transformed by mechanical means into a black and white stipple picture. If a sort of file made of indiarubber is inked and pressed against it, large dots of ink with scarcely any white intervals will be left upon the high parts of the relief, which press into and crush down the inked indiarubber points, while in the hollows the dots will be small with consequently a large proportion of whiteness remaining. Or if a relief has its surface covered with ink, and is then traversed all over with a V shaped tool cutting grooves which have a uniformly level base, finer lines of ink will be left on the higher parts of the relief than upon the lower parts. These are examples of the methods that have been proposed for getting a stipple or grain.

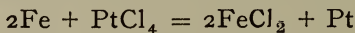
Excluding the photo-mechanical processes described in the last chapter, printing surfaces are of two kinds: those in which the subject is sunk or incised in the plate, called *intaglio*, photo-engraved, or etched plates; and those in

which the subject stands up in relief as in ordinary wood blocks. The first are printed from after the manner of getting impressions from copper or steel engravings or etchings, the ink being caused to fill the depressions and being taken up from these by the paper. In using the second, the ink is merely rolled on to the parts that stand up in relief, and the paper being pressed upon the inked surface takes the ink from the top of the projections. The first method gives the finest results, but the second has the great advantage of being similar to ordinary typographic printing, and a photo-relief block or typographic block may be incorporated with type and printed from with the type.

Whether an intaglio or a relief surface is desired, the principle of the operations is generally much the same. A suitable surface, more often of zinc or copper than of anything else, is made to receive a photograph that shall allow an etching fluid to attack certain parts only of the plate. For an intaglio plate the image itself is etched, while for a relief block it is the ground that is lowered by corrosion.

The first permanent or fixed photographs that were produced were made by Nièpce, by coating a copperplate with mineral bitumen by means of a solution of it in oil of lavender. This was exposed under the design to be copied, those parts of the film not affected by the light remained soluble and were dissolved away, and the plate was subjected to the action of an etching fluid. An intaglio plate was thus produced.

In 1852, Fox Talbot patented the production of photo-etched steel plates for printing from, by coating the plate with chromated gelatine, exposing under the *cliché*, and then washing. The etching was done with a solution of platinum chloride which dissolves iron thus—



The ferrous chloride and precipitated platinum are easily washed away.

To protect as desired certain parts of a plate that is to be etched, a print may be transferred on to it, or a suitable carbon print may be developed upon it. Printing surfaces are also produced from gelatine reliefs by casting and electrotpe processes.

CHAPTER XXV.

REPRODUCING NEGATIVES (ENLARGING, &c.)

REPRODUCED negatives are required sometimes merely because more than one negative is wanted, and very often because the negative is to be enlarged or reduced, or because it is wanted reversed for carbon printing or for one of the photo-mechanical processes.

The simplest method of getting a positive enlargement is to put the negative in an enlarging apparatus, and receive the image upon a sensitive surface. It is possible to get a print in this way on prepared paper not more sensitive than ordinary albumenised silver paper where direct sunshine is available, but this method is very rarely practicable in this country. By substituting, however, an emulsion coated paper that requires a short exposure only and is then developed, the need for sunshine disappears, and artificial lights are quite efficient. Projecting lanterns specially made for direct enlarging are now made of a variety of patterns.

But although this method is rapid and often useful, it has two or three disadvantages. In the first place, the print must be on sensitive material that rapidly receives the desired effect, and the certainty of permanency that characterises platinum printing and printing in pigment cannot be secured. The faults are enlarged as well as the image, and there is less opportunity of getting rid of these than when an enlarged negative is produced.

A negative may be reproduced the same size by taking advantage of the reversing action of light. One method of doing this is given in the chapter on solarisation and halation. In this case the new negative is reversed.

A reproduced negative is not reversed when it is obtained by two printings, first by exposing under the original negative to get a transparency, and secondly under

the transparency to get the new negative. The sensitive material used for these operations may be gelatino-chloride or gelatino-bromide plates, or carbon tissue specially prepared with a full amount of extra fine pigment. The carbon process gives the finest results. The chief points to attend to in preparing transparencies for reproducing negatives is to get full detail, even if a little fogging is necessary, and to reproduce the gradation of the original without loss.

If a reversed negative is wanted of an object that has to be photographed, the usual method is to fix a mirror in front of the lens at an angle of 45° with its axis, and so to photograph the reflection in the mirror. The mirrors used must, as has already been explained, be coated with silver on the *front*, and the metal, being exposed, soon tarnishes, and is liable to injury. The mirrors require careful cleaning to keep them in good order, and sometimes need resilvering after a year or so. If, therefore, a reversed negative is wanted only occasionally, it is more practicable to resort to other means, though they may be less perfect.

A reversed negative may be obtained by the old, if not well-known, method of putting the sensitive plate with its glass side towards the lens. It is necessary to take care that the glass is quite clean, that the film is protected from injury by the spring or separating sheet of the camera back, and that in focussing the thickness of the glass is allowed for. This last is the most uncertain item in the work, and though it may be neglected when a small stop is used in the lens, and will sometimes even improve the outdoor work of an inexperienced operator by putting the foreground into better focus, it is a matter that needs careful attention in exact work.

Film or paper-supported negatives that are thin enough may be printed from either side, and the difficulty of reversal disappears; but it is necessary to bear in mind that very few films are thin enough for this purpose. However thin the film negative is, there is a loss of definition in the print by printing from it in the reverse direction, and whether this loss is harmful or not is easily ascertained by taking a silver print from each side of the negative and comparing them.

It is easy to get a reversed negative if an enlargement is to be made, by using the camera for the production of the negative, and placing the transparency with its glass side towards the lens. If a full-size transparency is made, and this is copied in the way described, the flaws in the glass will not be enlarged.

A gelatine negative may be itself enlarged to as much as two diameters, it is stated, and if the gelatine is thicker to a still greater extent, by soaking the negative in water containing about a twelfth of its volume of strong ammonia. In about two hours, perhaps, the film frills off the plate, and if it is not distended sufficiently the temperature of the bath may be raised by adding small quantities of hot water. The film is then caught upon a glass plate of sufficient size and allowed to dry. It is obvious that the film may be turned over before it is put on the new glass and a reversed negative obtained. Since 1878, when this method was published, many photographers have announced the crude fact that a gelatine film would frill, and that when frilled off it was enlarged.

But whether the frilling off method is to be depended upon or not, in the majority of cases, when an enlarged negative is required, the original negative must be preserved intact. The enlarged negative must then be made through the medium of a transparency, unless the dusting on process is resorted to. There are, then, two distinct methods available, namely—the transparency may be printed by contact from the small negative, and the enlarging done from the small transparency, or the small negative may be enlarged to a large transparency, and the large negative may be printed by contact from this. There is something to be said in favour of each plan. In producing the enlargement direct from the small negative; that is, making a large transparency, the flaws of the transparency are then not enlarged, and it is far easier to eliminate defects. The large transparency offers particular facilities for producing one or many enlarged negatives by a printing out process, as, for instance, on albumenised silver paper, after the plan of V. Blanchard. Very excellent results are obtained in this way, the sensitive paper being

exposed rather longer than it would be for a positive print, then washed, fixed, dried and waxed. No toning is necessary, and such paper negatives appear on the whole to be more stable than ordinary toned prints. If necessary, new negatives are easily made, and each new negative is as exact a reproduction of the first as is possible.

In favour of making a small transparency and enlarging from it, we may say that a printing process is then available for making the transparency, and that the carbon process lends itself very kindly for this purpose. From a good transparency negatives of any size may be produced with facility.

The negative or transparency that is to be enlarged must be illuminated equally all over, and then it only remains to expose the large plate in the camera with ordinary care to get a successful result.

An evenly-illuminated surface is often difficult to secure. If, for instance, the transparency is fixed in a window, objects at a very considerable distance—even two or three hundred yards away—will cause thin places on the large plate if they are included between imaginary lines drawn from the lens through the extremities of the transparency to the view beyond. The operator may be tempted to think that such objects being so far out of focus cannot influence his work, but he will find himself grievously mistaken if he rests upon this assumption. With a good expanse of fairly uniform sky there should be no difficulty when the transparency faces directly towards the sky. The sky also, if it is uniformly brilliant, may be used by means of an inclined reflector; but the reflector must be kept carefully clean, and be large enough to include, as it stands, the whole solid angle formed by the lines that might be drawn from the lens through the extreme corners of the transparency. If the transparency is 5in. by 4in., and the picture is the horizontal way of the plate, and the reflector inclined at an angle of 45° , a reflector that is 12in. by 10in. will be found to allow no practical margin when the optical centre of the lens used for enlarging is 8in. distant from the transparency. A white surface, such as a sheet of white paper, may be used instead of the reflector, but exposure

will have to be considerably prolonged, and if the white surface is not evenly illuminated the enlargement will suffer.

The simplest method where daylight is employed is to interpose a translucent substance between the light and the transparency. The translucent medium then becomes the source of illumination, and with a little care variations in the intensity of light that different parts of its surface receive may be so toned down as to be practically eliminated. Ground glass may be used for this purpose, but nothing, probably, can equal opal glass. The opal has no grain, and its diffusing power is vastly superior to a couple of sheets of ground glass. Either pot or flashed opal is suitable, if not too dense. Whatever is used, it should be placed at least two or three inches from the transparency.

To enlarge by artificial light a condenser properly used does away with all difficulty. But large condensers are expensive, and small ones are not of general utility. A condenser eight inches in diameter is the smallest that will serve with a half-plate negative, and this supposes always that the transparency is placed close to the condenser, a position that will rarely be the best. The smaller the source of illumination, the more easy will it be to arrange the apparatus to give perfect results. The function of the condenser is to turn the diverging rays that impinge upon it into a bundle of converging rays, and the enlarging lens should be placed where it can receive, as far as possible, the whole of the light that passes through the condenser.

But a condenser is not necessary if a uniformly-lighted surface can be produced. Ground glass has been often recommended as a light diffuser, but it shows to far less advantage with artificial lights than with daylight, because artificial lights are of necessity more concentrated. Opal glass, however, is just able, with care, to give a satisfactory result. If four or six flat-flame burners are arranged in a group, so that their flames form, as nearly as possible, the required surface of light, and a sheet of opal glass is placed half-way between the flames and the negative, the illumination of a 5 by 4 or half-plate transparency will be

found fairly satisfactory. It is well to put a piece of white porcelain—a porcelain dish, for example—behind the flames to act as a reflector. The gas flames cannot be within five inches of the transparency without danger; the opal glass is then two and a-half inches in front of the flames. With these distances and a 5 by 4 transparency, the gas flames must be made to extend very nearly to the edges of a rectangle about seven inches by eight inches, and if the piece of opal glass is the same size, it will allow only a very small margin for misplacement. The burners may be screwed into a piece of bent brass tubing, with one end closed, and suitable holes in it; and the lower burners should point forward a little, that they may not cause the upper flames to flicker.

APPENDIX

ON TESTING LENSES.

THE quality and value of a lens cannot be determined by an inspection of the picture produced by it. A cunning operator can make an inferior lens appear the better by selecting a suitable trial picture, as, for example, in one case known to the author where a street view was chosen. The houses on both sides were near the camera, and the centre of the view was distant from it, so that, with the same apertures and focal lengths, the better picture was, of course, got by means of the lens that suffered most from curvature of field. For that particular view this fault was a virtue, and the results were accordingly deceptive.

Unless the difference between lenses is very marked, it takes a long time and very shrewd analysis of their ordinary routine productions to form any usefully correct judgment of the comparative merits of the instruments. Anyone can distinguish a knob of glass from a lens, but to decide between two lenses made by reputed makers requires far more knowledge and experience than most photographers can lay claim to. The eye must be trained to see, and the hand to work, before either the observation or the manipulation in lens testing is accurate enough to merit the name of scientific. The following hints may, however, be useful.

In almost every lens, including even the single lens, the mount is more or less in the way. It acts as a diaphragm towards the edges of the plate, and is thus the chief cause of the rapid falling off of the light there when large apertures are employed. This defect may be estimated by fixing

the lens on a camera and racking out the focussing screen to its proper position for the lens, or focussing some distant object. The screen is then thrown back, the eye is brought to the place formerly occupied by one corner of it, and the stops are put in the lens one at a time, beginning with the largest, until one is found that appears its true shape, because its opening is not at all hidden by the mount. This stop is the largest that should be used for general landscape work with the full-size plate, and the smaller the figure got by dividing the diameter of this stop into the focal length of the lens the more satisfactory is the instrument in this matter.

It can be discovered whether the combinations in a doublet are truly mounted with regard to each other—that is, if the centring is correct—by holding the lens at arm's length and looking through it at a fairly distant gas or candle flame. The reflected images of the flame should be one behind the other in a direct line. It is not possible to see them all when they are superimposed, but by turning the lens a little to and fro it will easily be seen whether they gradually come together as they ought. There are six reflected images produced by a doublet that has both its combinations cemented, and in a portrait lens of the ordinary or Petzval construction, in which one of the combinations has its components separated, there are fourteen images produced by reflection that are easily seen, and one other that is a little difficult to find. The number of images is greater than with the symmetrical doublet, because the reflecting surfaces are six instead of four.

The glass itself of which lenses are made may vary in its physical properties. The colour may be compared by placing the lenses, removed from their mounts, on a sheet of white paper, and looking at them in good daylight. It should be borne in mind that larger lenses must generally be also thicker, and that therefore they will appear to have more colour, though they are made from the same specimens of glass as smaller and apparently more colourless combinations.

Some specimens of glass, especially crown glass and the

denser qualities of flint, are liable to form an iridescent film of tarnish upon their surface, and the scattering effect this has upon the light is fatal to good work. If such a film appears after the carefully-cleaned lens has been kept in a suitable place—that is, not exposed to deleterious fumes, &c.—for a month, the glass is not good. An otherwise first-class lens may show this defect, and it must not invariably be considered as a mark of carelessness on the part of the maker. There is no cure for this trouble, the defect is inherent in the glass. No first-class optician would refuse to exchange an instrument of his manufacture that suffered from this defect.

Small bubbles are difficult to avoid in larger pieces of glass. Although bubbles are not desirable, the photographer need not trouble about one or two if their size bears a very small proportion to the smallest stop, especially if they are near the edges of the lens.

With regard to those matters that are affected by the making of the lens, the presence of a flare spot—that is, a spot of light produced by the lens opposite its centre, which fogs the plates at that part—must at once condemn any instrument. This fault may, perhaps, be easily cured by the optician. It should be expected to show chiefly in outside work, especially when a bright sky forms a part of the picture.

The doublet lenses of even the best makers sometimes produce a ghost of false image. To test for this, focus a gas or candle flame that is eight or ten times the focal length of the lens distant from the camera, cover the head with a dark cloth, and bring the image of the flame into the centre of the focussing screen. Now carefully turn the camera so that the image moves slowly towards one side, and look for the ghost moving in the other direction, exactly opposite to the chief image. The ghost may not be in focus when the chief image is, but, if present, it can generally be focussed without difficulty, and then it will be seen to be an erect image of the flame. Although some of the best lenses show this fault, it is obvious that it may prove troublesome, especially in outdoor work, as if, for example, a bright cloud comes on one side of the plate,

dark foliage in the foreground on the opposite side must suffer a certain amount of fogging.

If a lens is not ground true, or the glass of which it is made is not homogeneous, its irregularity will cause a more or less irregular refraction of the light, and, therefore, a blurred image. The amount of blurring may be scarcely appreciable, and as other causes may, and generally will, interfere more or less with the sharpness of the image, this affords no specific test for the trouble in question. By using a small stop, the effect of each part of the lens is localised on the image if we are using a single lens, and with a doublet correspondingly small parts of both combinations work together. Now, if a part of either lens that is not much smaller than the stop used is too flat or raised into a bump, or is otherwise irregular, that part of the image that depends for its production upon that part of the lens will be out of focus or blurred. Perhaps a clean newspaper sheet is the handiest object to make this test with. It must be flat, square to the camera, its centre in a line with the axis of the lens, and, if possible, facing a window, that the whole surface may be evenly illuminated. As the image produced on the ground glass when a small stop is used is not often bright enough to examine critically, and is always interfered with by the grain of the ground glass, it will be necessary to make a negative and examine that instead. The negative should be examined under a lens, and if a part is found that is not well defined, and the sheet itself shows no sign of having been the cause of the irregularity, we may conclude that the lens is at fault. There may be a slight falling off of definition towards the edges, but this should be uniform at any given distance from the centre of the plate.

Spherical aberration causes a want of sharpness in the image, and, if excessive, causes a halo round the image of a bright object such as a gas flame. To test for this fault, therefore, focus a steady flame on the focussing screen, and look for a halo, and examine the sharpness of the image by means of a magnifier. These tests should be made with the full working aperture.

The coincidence of the visual and actinic foci should

also be examined with the full aperture of the lens. Arrange five or seven well-defined black and white subjects, such as white cards with black devices upon them (playing cards, for example), so that they form a series of steps, all facing square to the camera, but each an inch in advance of the next to it. Then focus carefully on the middle one, expose, and develop. If any other card than the middle one is better defined on the plate than it, the lens is not properly corrected. To eliminate any want of correct register in the camera, focus on a temporary screen held in the same back (keeping the back open) that the sensitive plate is afterwards put in.

To test for curvilinear distortion bring the image of any convenient straight line, such as a window frame, close to the edge of the focussing screen, and observe how far the middle of the line is bowed outwards. This refers to single lenses; symmetrical doublets would give a scarcely recognisable amount of distortion even if carelessly made.

Given the same rapidity and focal length, methods for determining which have been already described, two very important points of comparison are the covering power and flatness of field. For covering power, adjust the lens to a camera with a larger focussing screen than the lens is made to cover, and see how far from the centre of the screen, on both sides, you can bring the image of some suitable object that is not nearer than about ten times the focal length of the lens, without losing the power to focus an intelligible representation of it. The face of a watch is a good object to use.

At the same time astigmatism may be looked for. This fault, practically expressed, is the impossibility to get a vertical and a horizontal line into focus at the same time. It shows especially towards the edges of the field. If the thick strokes of the watch face are too heavy, compare the fine strokes of the X's in the figures twelve and nine.

Flatness of field may be compared by the same arrangement. The lens should have its full aperture, and the object should be exactly focussed at the centre of the field, and the position of the focussing screen marked on a

piece of paper gummed to the baseboard of the camera. The camera is turned until the image occupies in turn two or three measured distances on each side of the centre, and in each position the image is focussed as sharply as possible, and the position of the screen recorded. By drawing a straight line upon a sheet of paper, and marking at the proper distances from its centre the position of the focussing screen, the shape of the field of the lens will be shown. For this test to be exact, the optical centre of the lens should be the centre of revolution of the camera.

There are, perhaps, no other tests which the photographer, as such, can profitably apply to lenses that he wishes to compare. "Depth of focus," as it is called, is not a question of the quality of the lens, but of the aperture and focal length. An inferior lens may show apparently a greater depth of definition, chiefly because it is inferior, and, giving no sharp image at all, is not better at defining things a little out of focus, but unable to define those that ought to be in focus.

It may not be necessary to look at a lens from all the points enumerated to form a fairly certain judgment of its quality. Mr. William Ackland stated many years ago, that he had professionally sorted out a number of first-class instruments from the mixed importations of French portrait lenses by examining their centring, their covering power, and their achromatism. He further adds that those he selected were charged at a considerably higher price, and that he did not know of a single case in which the selected lenses failed to give satisfaction.

ENGLISH WEIGHTS AND MEASURES.

MEASURES OF BULK.

60 minims ..	..	..	..	=	1 fluid dram
8 fluid drams ..	..	..	..	=	1 fluid ounce
20 fluid ounces ..	..	..	..	=	1 pint
2 pints ..	..	..	..	=	1 quart
4 quarts ..	..	..	..	=	1 gallon
1 minim ..	..	..	..	=	·91 grain of water
1 fluid ounce ..	..	..	..	=	437·5 grains of water
1 pint ..	..	..	..	=	1·25 lbs. of water
1 gallon ..	..	..	..	=	10 lbs. of water

MEASURES OF WEIGHT.

Avoirdupois Weight.

437½ grains ..	..	..	..	=	1 ounce
7000 grains ..	..	..	..	=	16 ounces = 1 pound

Troy Weight.

24 grains ..	..	..	..	=	1 dwt.
480 grains ..	..	..	..	=	20 dwts. = 1 ounce
5760 grains ..	..	..	..	=	12 ounces = 1 pound

COMPARISON OF THE ENGLISH WITH THE METRICAL SYSTEM.

MEASURES OF LENGTH.

1 millimetre ..	..	..	..	=	·03937 inch
1 metre ..	..	..	..	=	39·37 inches or 3·28 feet
1 inch ..	..	..	..	=	25·4 millimetres

MEASURES OF BULK.

1 cubic centimetre (c.c.) ..	..	..	..	=	·0352 fluid ounce
1 litre ..	..	..	..	=	35·2 fluid ounces or 1·76 pints
1 fluid ounce ..	..	..	..	=	28·4 cubic centimetres

MEASURES OF WEIGHT.

1 gramme ..	..	..	..	=	15·43 grains
1 grain ..	..	..	..	=	·0648 gramme
1 ounce <i>avoir</i> ..	..	..	..	=	28·4 grammes
1 ounce <i>troy</i> ..	..	..	..	=	31·1 grammes

COMPARISON OF FAHRENHEIT AND CENTIGRADE THERMOMETERS.

CENT.	FAHR.	CENT.	FAHR.	CENT.	FAHR.	CENT.	FAHR.
100	212	70	158	40	104	10	50
95	203	65	149	35	95	5	41
90	194	60	140	30	86	0	32
85	185	55	131	25	77	— 5	23
80	176	50	122	20	68	— 10	14
75	167	45	113	15	59	— 15	5

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